The
GEOGRAPHICAL JOURNAL

Vol XCVII No 2 R.G.S. *February 1941*

VENEZUELA IN 1940

A. E. GUNTHER

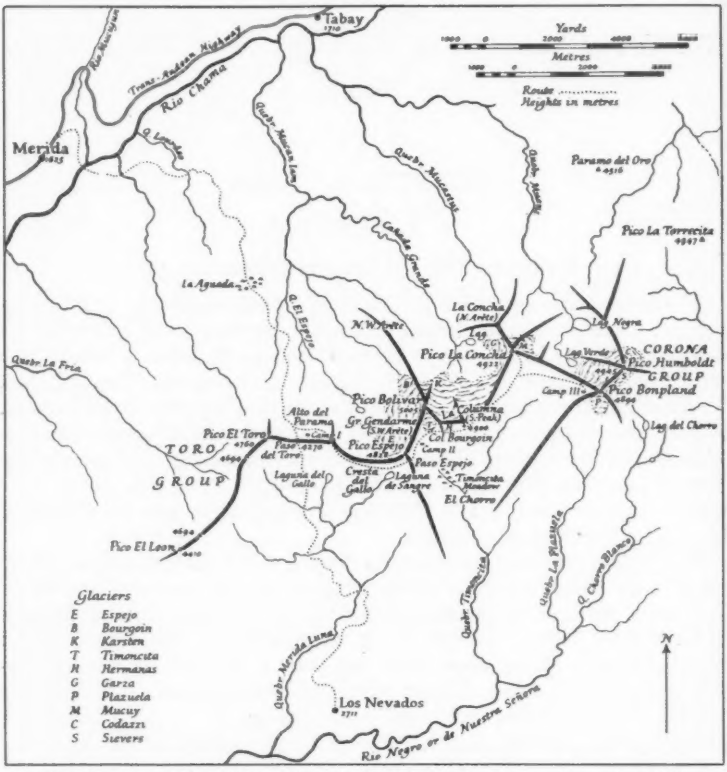
Continued from the January Journal, p. 53

The third great geographical province in Venezuela comprises the mountain regions. These extend the length of the country in a broad belt from the Colombian border in the west to the mountains in the State of Sucre in the east where the Bocas del Dragon or Dragon's Mouths cut them off from Trinidad's northern range. Here and there this belt is broken as by the Gulf of Barcelona, or by the gorge of the Rio Cojedes near Barquisimeto forcing a wide alluvial fan through a break in the range and linking the deserts of the State of Lara with the "Ilanos" of the Apure Basin There is no break to the west, though the Cordillera de Merida narrow and dip to meet the Cordillera Oriental at the Colombian border.

The mapping of this great mountain range is still in its early stages. There are no maps as we have them of European mountains, nor any like those of Trinidad's northern range, a small thing by comparison. Even of the hills in the Federal District, La Silla de Caracas climbed by Humboldt in 1800, there are still no hikers' maps. Here and there a "survey" for mining, geological maps for the study of deeper oil levels, for roads or cities, or for a study of glaciers, has led to sketch-maps, and portions of the range have been photographed from the air. But the systematic survey of the mountain regions of the country is work undone.

The high Andes of Venezuela are an extension of the great Andean chain which runs the length of the Pacific coast. The Cordillera Oriental, which branches off from the main chain in Colombia, is linked by the Sierra de Perija to the Sierra de Santa Marta, that isolated group of glaciated summits rising over 17,000 feet above the Caribbean. A north-eastern extension of this Cordillera crosses into Venezuela near San Cristobal, and rises gently until above Merida it culminates in the Columna and Corona groups into peaks over 5000 metres high. The length of this range within Venezuela is 400 kilometres, its breadth 100 kilometres, commanding the Lake of Maracaibo to the north and the basin of the Apure river to the south, forming the water-

shed between them. Farther to the north-east still the Andes sink gradually into the desert plains of Barquisimeto. Between Valera and Merida they split into two parallel ranges, the Sierra de Merida and the Sierra del Norte (La Culata) divided by long, deep-cut valleys, the Rio Motatan rising south-west from Valera and Timotes, and the Rio Chama rising north-east from Merida: valleys which meet in one of the highest road passes in the world, the Alto de Paramo de Mucuchies, over 4000 metres above sea-level.



Sketch-map of the Sierra Nevada de Merida by the author, after Jahn

In their middle reaches these valleys are filled with immense masses of alluvial deposit of glacial age which form a succession of *mesas* or terraces reaching altitudes of 300 metres, up which the trans-Andean highway runs in deep-cut gorges. In the temperate zone these mesas are the site of some of the most attractive townships, such as Timotes and Merida, lying 6000 feet above sea, where vegetables and flowers are grown for the foreign communities dwelling in the tropical oil fields of the Maracaibo basin.

Above this temperate belt the real Andes begin. Maps of the mountainous districts of South America are shown with the names Nevada and Paramo.

Corona group from north: Pico Humboldt (left) and Pico Bonpland (right)

Phot. E. M. Chenery

At Mucurba, State of Merida

Pico Humboldt (left) and Humboldt Glacier from Concha-Bonpland saddle

Pico El Toro, and track from Paso del Toro (right) to Los Nevados: Frailejon in foreground

Concha-Bonpland saddle

to Los Nevados: Frailejon in foreground

The word Nevada indicates a mountain that rises into the limits of perpetual snow. Paramo signifies a region within the Alpine zone where snow falls often but quickly disappears. Thus the names give some indication of the altitude to which the Andes rise.

The aspect of the Andes varies greatly from that of the Alps. The Paramos are their main topographical feature and give them a unique attraction. The panorama is of a high plateau, or *gipfelflur*, standing at a constant altitude of about 13,000 feet, in appearance a mature landscape, rounded and smoothed by glacial action. The ice-cap may have been of the plateau type. Glacial erosion, though everywhere evident, is most marked among the peaks of the Sierra de Merida. Here glaciers have cut deep into the range; U-shaped and hanging valleys, corrie lakes and moraines are common; but the terraced, mesa deposits with gorges of later erosional cycles are a feature of the Andes. Only the serrated crests of the Sierra de Merida with their pocket glaciers, standing ribbed and bare out of the Paramos, rising 3000 feet above them, bear any resemblance to the Alpine scene.

For high mountains the rainfall is low. The vegetation though scanty is rich, a low-lying Alpine flora, grasses and scrub, the most prominent being the Compositae, of which the large silvery rosettes of the Espeletia,[1] a whorl of donkey ears crowning stems 4 feet high, stand out as glistening pin points against the dull tones of the mountain background. A bright reddish-purple Senecio, like a large Michaelmas Daisy, is also common, and a species of Chaetolepis with rosy red flowers covering bushy scrub 2–4 feet high, gives a colour to the slope reminiscent of a Scottish hillside in August. There are St. John's Worts, Calceolarias, a Monnina, Gentians, Pernettya, Vaccinium, Sisirynchium, and others too numerous to mention. The colour of the many ferns, mosses, and lichens, ranging from ochre to red and grey, gives tone to the beauty of the Paramo.

If the plateaux of the Paramos are beautiful, the valleys above the temperate zone are no less. They support a scanty population close in line to the Indians of pre-history who have left the radical *muchu* in place-names, and who in grit and temperament have few equals in these latitudes. They have given their country more than one of its foremost Presidents. Their villages, with baroque churches, washed, red-tiled houses and inns of mediaeval simplicity with inside court and stable, reflect the Spanish influence. With the growth of population, and with the exhaustion and denudation of the soil lower down the valleys, cultivation is extending upwards into the less fertile regions. These peasants scrape the thin soil with wooden ploughs for a stunted corn, lending patches of yellow to the browns and greys of the high valley slopes.

The development of the petroleum industry has given much impetus to a region even as far from the current of world affairs as the Andes. It is possible to see two phases in the growth of interest in mountain exploration, that before and that after the war. The first period may be said to start in the late 1860's, with the excursions up the Pico El Toro in 1868 led by Dr.

[1] Dr. Chenery of the Imperial College of Tropical Agriculture in Trinidad has successfully raised these Espeletia from seed in the east and north of Great Britain.

P. H. G. Bourgoin, Professor of Botany at the University of Merida. This was followed in the '70's to '90's by a number of expeditions, mainly scientific in aim, of which those of the traveller Engel, Goering the painter, Hamel the ornithologist, Sievers the geologist, and Goebel the botanist, are the best known. In how far these expeditions were inspired by the golden age of mountaineering in Europe, or by Whymper's ascents among the Andes in the '80's is a matter of conjecture, but none appear to have been actuated by a desire to attain the highest points of this range. Mountaineering had not then started. One of the greatest names in the history of Venezuelan exploration during this period, whether for the Andes or for other parts of the country, is that of Dr. Alfredo Jahn. By origin German, by profession an engineer, and by inclination a naturalist, he climbed the first of the giants, the Pico Humboldt (4938 metres), in 1911, made the first glacier observations in the Sierra de Merida, and produced the first map. For Dr. Jahn natural history came before ascents, and it is probably due to this that his attempts in 1915 on the Pico Bolivar, the highest summit in Venezuela, failed and that he left the other giants unclimbed.

The second period follows the last war and coincides with the post-war development of the oil fields in the Maracaibo Basin. The names of Venezuelan nationals are found together with those of foreigners spending a part of their local leave from the oilfields on a tour of the Andean regions as a break from a tropical climate. Of those of Venezuelan nationality that of Dr. Enrique Bourgoin, the grandson of the pioneer of the 1860's, deserves to be known; for long the moving spirit of a Committee intent upon the conquest of the Pico Bolivar, he and Dr. Franz Weiss made the first ascents in 1935 and 1936. The later climbs by Jagenberg, Stolk, and Notz should also be mentioned. Of the foreigners Dr. M. Blumenthal attempted the Pico Bolivar in 1922, and wrote the first account of the Venezuelan Andes to appear in a foreign journal, the Swiss Alpine Journal. A later attempt was made by Luthy and Smith in 1931 which like that of Blumenthal failed, as did other attempts on account of weather or sickness.

Since the first ascent of the Pico Bolivar in 1935–36 all of the Big Four have now been climbed; the first recorded climb of the Pico la Concha was made by Weiss and myself in 1939, and that of the Pico Bonpland and the Columna South Peak by myself in 1940.

On the south side of the Sierra de Merida, built upon a Mesa commanding the valley of the Rio Negro or Nuestra Señora, lies the village of Los Nevados, linked to Merida by a mule track crossing the range by the Paso del Toro, a saddle between the Pico of that name and the Pico Espejo to the east. This track has been used for a century or so by the half-Indian herdsmen of the inner valleys as a trade route to the plains falling to the Lake of Maracaibo, and to-day it serves the climber as the nearest approach to the high peaks of the Sierra de Merida. Merida is the Innsbruck of Venezuela. The north face of the Pico Bolivar, 10,000 feet above it, forms an imposing background to piazza and cathedral. It is usual for expeditions to leave the city at sunrise, or as soon after as the muleteer can collect his mules, and to pitch the first camp on the rocky shelf of the Alto del Paramo beneath the Paso del Toro. The first step out of the city is that down the steep Mesa cliff to the bridge

Head of valley of Rio Nuestra Señora, Sierra de Merida

Phot. E. M. Chenery

Santa Rafael village, below Paramo de Mucuchies

South-west arête of Pico Bolivar (right) and Grand Gendarme (Piacho Vertigo) from Col Bourgoin

Piacho Vertigo and south-west arête of Pico Bolivar from summit

Gendarme (Piacho Vertigo) from Col Bourgoin

summit

over the Rio Chama. The route up the south side of the valley is a pleasant change after the tropics. The temperature of the early morning is chilly. The lower farmsteads or haciendas are rich in a mixture of temperate and sub-tropical vegetation, coffee, cacti, roses, and geraniums, giving way on the higher slopes to dense forests rich in bamboo and festooned with lichen, which, like draped bunting, marks the mean cloud level of the rainy season. At 3000 meters the forest breaks into the broad day of the Alpine Zone, the zone of the Frailejon, reached about noon, and it is usual to spend the midday hour at the thatched shelter of L'Aguada, a half-way house, the night refuge of road gangs, or of traders from Los Nevados who sleep through the heat of the day to reach Merida by evening.

The view expands during the afternoon ride. The Columna Group, falling in the long cliff rampart of the south-west arête and of the Pico Espejo, rises grandly across a deep-cut glacial valley. In the valley of the Rio Chama, beneath the slopes of the Sierra del Norte, lies the long narrow ribbon of the trans-Andean highway with spots of civilization here and there. The city of Merida is spread like a chequer board on its gently sloping mesa, and the twin church towers of Tabay are like toys in the valley.

The second day, from Camp I to Camp II, is a day on the Paramo contouring the frailejon-covered slopes of the Cresta del Gallo, passing the Laguna Sangre (a spring, welcome to sufferers from *mal de paramo*), and climbing to the Paso Espejo. The Pico Espejo (4828 metres), higher than the summit of Mont Blanc, was the highest point reached by Dr. Jahn's parties, and was the site of Blumenthal's highest camp. It commands the whole Columna Group and the cirque of the Timoncito Glacier, preferred by later parties as a base camp. To this one descends from the Paso Espejo by a traverse of the steep cliff walls of the Bolivar's south-west arête, a *mauvais pas* of 500 feet. Camp II is magnificently situated. The cliffs of the south-west arête rise a few feet from the tents pitched on an alluvial fan near the snout of the glacier, the route to the Pico Bolivar. This and the Columna South Peak can be climbed in 90 minutes by a fit party. It was from here that the traverse of the south-west arête of the Pico Bolivar was made in 1939, culminating on the summit of the Pico, but leaving the Piacho Vertigo, an isolated Grand Gendarme, the only unclimbed pinnacle of this group to a "north wall" party of a future day. The Pico la Concha, and the Pico Bonpland to the east, may both be climbed from Camp II in a day, though it is better to bivouac at Camp III at the head of the immense amphitheatre of the valley of the Rio Nuestra Señora, from which the Pico Humboldt is more accessible. The ascent of the Pico la Concha is a rock scramble, the only remaining glaciation lying in the cirque of the steep north slope.

Both the Pico Humboldt and the Pico Bonpland are glacier climbs from the north, rock from the south. The expedition of 1940 pitched a camp at the snout of the Plasuela Glacier. The route up the Pico Bonpland was ice all the way to the 100 feet of rock ridge at the summit. In 1911 Dr. Jahn had attacked the Pico Humboldt from the south. He had camped near the Laguna de Chorro (3603 metres) and then by the Sievers Glacier made a rock ascent except for the névé slope from the Bonpland-Humboldt saddle; on the whole an easier route than from the north. The route to the Pico Humboldt from the

Plasuela Glacier (Camp III) would pass through a cleft in the north arête of the Bonpland and then follow up the Humboldt Glacier, the largest in these latitudes, and though much crevassed affording, after fresh snow, a splendid ski-ing slope. The Humboldt Glacier falls to the north into the narrow valley and corrie lake of the Laguna Verde, green from half-melted waters; lower down, the valley widens and the stream meanders through meadows of green sward into the black waters of the Laguna Negra, an immense square of water from which hills rise steeply into the higher Paramo.

Thus the most inaccessible peak among these mountains is within four days of Merida, a week's return, though there are few parties that escape a delay due to the *mal de paramo*, the insidious sickness which attacks climbers coming into the cold, dry air of altitude from the heavy damp heat of the tropical plains.

It is impossible to travel in a country like Venezuela, a large part of the northern margin of a continent, without being impressed with the immensity of it, fascinated by the variety of scenery and of people, and thrilled by the beauty of it. The aeroplane has placed the farthest ends of this great country within a few hours of one another. One can now within a few days enjoy the width and spaciousness of the Mesa and Llanos plains, with their 180 degrees of sky; bathe in the azure waters at the feet of the white limestone cliffs of the lovely Sucre coast; bake in the cacti deserts of Lara or the desiccated wastes of Falcon; cut traces through the tropical rain forests of the great river basins, or keep out arctic cold in a five-ply sleeping bag in the glacier mountains of the Sierra de Merida, and sleep under the wide canopy of stars.

Venezuela is a country that goes back far into history and it is rich in tradition; many races and nationalities have contributed to its making; but marked national characteristics have been merged, not lost. More arresting even than these, are the country's prospects for the future. If one thinks of Venezuela as the Spaniards found it, of the stagnation that preceded the Liberation; even of the days, scarcely a quarter of a century ago, before an international industry spurred to modern development, one cannot but admire the achievements of the Republic to-day; they are the happiest augury for the time that lies ahead.

DISCUSSION

Before the paper the PRESIDENT (Field-Marshal Sir PHILIP CHETWODE) said: Mr. A. E. Gunther, who is to lecture this afternoon upon the Sierra de Merida of Venezuela, is the son of the late eminent creator and first director of the Museum of the History of Science in the University of Oxford. Our lecturer's brother, Mr. E. R. Gunther, was one of the first to be appointed to the Scientific Staff of the Discovery Committee. His death by accident on active service was a great loss to science.

Mr. A. E. Gunther has travelled widely in the world as an oil geologist, and makes this afternoon his first appearance upon our platform to describe recent work in the Sierra de Merida.

Mr. Gunther then read the paper printed above, and a discussion followed.

Mrs. CARSON ROBERTS: What is the present height of the snow-line?

Mr. GUNTHER: The lowest point reached by the glaciers on the north flank of

the Sierra de Merida may be between 14,000 and 14,500 feet; and on the south flank, 15,000 feet. But the question is particularly interesting because there appears to have been a considerable retreat of the glaciers in the last seventy years at least. From Colonial times the five giants, the Picos Bolivar, Humboldt, Bonpland, Concha, and Toro were truly Sierra Nevada, snow-covered mountains. The mountaineers of the 1880's placed the snow-line at 4400 metres. In 1910 Dr. Jahn records the snow-line on the Pico Espejo at 4500 metres, and remarks that until 1927 a small patch of snow remained on the Pico el Toro, since disappeared. The first photographs taken in the last century show the Columna and Corona groups to be more glaciated than they are to-day. In 1940 only the Big Four were glaciated, the Picos Bolivar, Humboldt, Bonpland, and Concha, while but a meter or two of snow lies on the south shoulder of the Espejo.

The PRESIDENT: What particularly interested me in the lecture was the reference to discovery of fresh oil supplies, for oil means so much now and has meant so much during the past few days. It enabled General Wavell's forces to move no less than 70 miles in one night, whereas before the last war it would have taken three, or possibly four, days for the same force to move that distance.

We recently heard a lecture in the Society during which it was stated by the lecturer that he did not think there were more than another fifty years' oil supply in the world. He was speaking as one of the greatest authorities. Is the new field to which Mr. Gunther has referred a very deep one and likely to continue to yield or is it a more or less temporary supply?

Mr. GUNTHER: The question of the world's oil reserves is constantly being discussed among experts. I often feel that the greater the expert the shorter time oil is likely to last! Experts have been prophesying the most terrible things since the industry began in the 'sixties, and there is still over-production.

One must remember first of all the enormous extent of the existing fields, the known reserves, the world over. In Venezuela alone the Maracaibo fields, already fifty miles long, are twenty years old, and are still growing. In Eastern Venezuela the surface has hardly been scratched. There are still vast areas in South America, Russia, and Asia, of which very little is known but in which there are likely to be great reserves of oil.

Then, with the geological side one must consider the refining side. The great increase in the supply of high-grade petrols has been made possible, especially in the last fifteen years, by improvements in refining technique, cracking, hydrogenation, etc. To-day, very large quantities of heavy tar oil are left in the ground, either because they cannot be produced, or because they are uneconomic to refine. Refinery development will lead one day to the addition of these vast, latent reserves to the world supply. So that taking these two factors together I am inclined to be optimistic about the future.

The PRESIDENT: It now only remains for me to ask you to join with me in thanking Mr. Gunther for his most interesting lecture.

CONTINENTAL SLOPES AND SHELVES

PROFESSOR O. T. JONES, F.R.S.

Meeting of the Society, 20 May 1940

AROUND every continent is a relatively flat but gradually shelving submarine belt running out from the low tide mark. Its width varies greatly, but it is usually between 50 and 150 miles; its outer edge is arbitrarily but conveniently defined by the 100-fathom line. At or about this depth the slope of the sea floor usually increases and this steeper slope continues to 2000 or 3000 fathoms. The flat belt and the slope are called respectively the Continental Shelf and the Continental Slope. There is usually no clear separation between the foot of the Continental Slope and the deeper sea beyond. Sections are usually drawn to an exaggerated scale and the slope made like a steep mountain side, whereas its average present inclination is rarely more than 4 or 5 degrees, though locally it may be much steeper.

Accurate soundings for mariners were made over the Continental Shelf. Soundings in deeper waters were made by scientific expeditions or by companies engaged in laying cables. Repeated fractures of cables on certain lines led to the discovery of some of the deep submarine trenches that have attracted so much attention in the last few years. The difficulties of close sounding in deep water were, first the time involved in taking wire soundings and uncertainty whether the lead reached the floor vertically below the ship, and secondly in fixing the position of the ship astronomically or by dead reckoning. Carefully determined wire soundings were sometimes as much as 7 miles out of their correct position. When, a few years ago, much of the bottom was supposed to be relatively smooth such an error was not regarded as serious.

The great advances in our knowledge of submarine topography in the last ten years have resulted from improvements in marine surveying. By accurate "positioning" and by echo- or sonic-sounding continuous records can be made so expeditiously that it is possible to obtain very large numbers of accurate soundings and to portray the topography of the sea floor by contour lines. The handicap of submarine contouring is that the surface to be contoured is invisible.

In ordinary clear weather the position can be determined by resection from fixed points on land to a distance about 10 miles off low coasts, but as much as 50 miles off a high. Outside these distances the United States Coast and Geodetic Survey have developed methods which make use of the velocity of transmission of an impulse through water. Stations on shore are connected by cable to hydrophones at known points in the sea in about 15 fathoms. At intervals the surveying ship throws over the stern a small T.N.T. bomb timed to explode just below the surface; the explosion wave travels to the hydrophone and at the shore station actuates a radio transmitter. The time at which the bomb explodes and the radio signal are recorded on the ship, and the difference between these times, with the velocity of sound in sea water, gives the distance of the ship from the hydrophone. The position is given by the

intersection of arcs with their centres at two or more hydrophones. This process is termed radio-acoustic ranging. A sono-radio buoy with hydrophone and radio transmitter may take the place of the hydrophone and the shore station. By radio-acoustic ranging positions can be fixed in any weather up to 100 miles from the hydrophones, and the error is usually less than 1 part in 200. Such errors as exist are due to variations in the salinity and temperature of sea water and to the depth and character of the sea floor. In general lines of secondary buoys are laid to shorten the distance between the ship and known points. The distances between these buoys are sometimes determined by the taut-wire method developed by the British Admiralty. One end of a roll of piano wire is attached to a weight and dropped overboard at one end of the line; the ship steams along the line and pays out the wire over a recording sheave; when abeam of a buoy the length paid out is noted, and when about 15–20 miles has been measured the wire is cut and left at the bottom. In a closed traverse of up to 140 miles the closing error is under 5 feet per nautical mile. By a net of sono-radio and secondary buoys the position of any sounding can be determined very closely.

Echo-sounding is based on the principle of setting up an oscillator in the hull of the ship and recording the time interval between the departure of the signal and the arrival of its echo from the sea floor. In some forms a frequency of a little over 1000 vibrations per second is used, about 2 octaves above middle C. In other types a high-frequency is employed of 16,000–40,000 vibrations per second, above the limits of audibility, and therefore termed supersonic. The depth is the product of half the time interval and the velocity of sound in water. The values for varying salinity and temperature are set out in tables issued by the British Admiralty, who have for many years carried out investigations to this end.

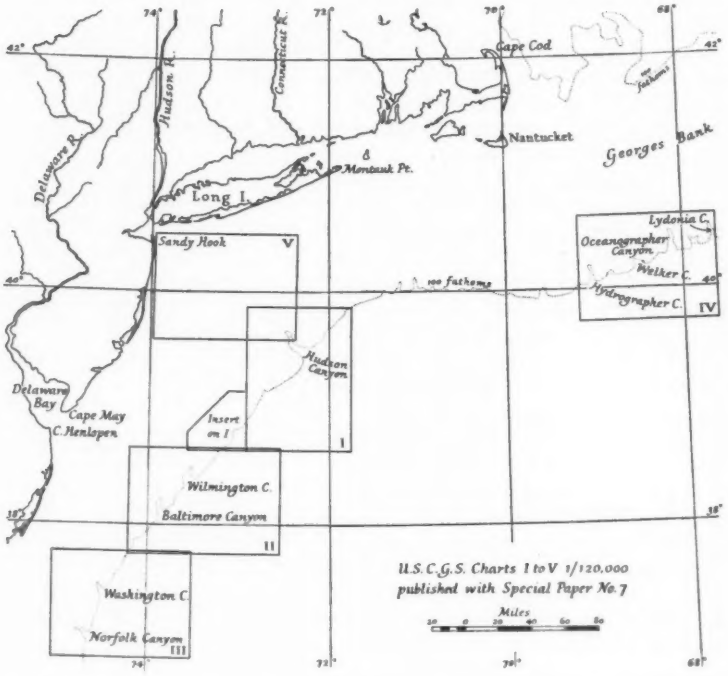
The signal is reflected from the nearest part of the floor, and if the bottom is sloping the point from which the echo is received is not vertically below the ship but on a perpendicular to the sloping bottom. If the sea floor is much broken a diffuse scattered echo returns and the signal is woolly or mushy. Strictly speaking the depth indicated by each echo should be corrected for slope, but over broken ground this becomes difficult and is usually ignored. If the sea floor is very much broken by narrow ridges and hollows the depth recorded is usually less than the greatest depth, and the floor is more irregular than the profile recorded by the instrument.

One of the first results of these new methods was the discovery near the Georges Bank, south-east of Nantucket, of a group of deep valley-forms trenching the edge of the Continental Shelf and going down the Continental Slope to a considerable depth. This revived interest in features which had been recorded many years earlier and described as submarine canyons. Before the era of echo-sounding and accurate positioning a sounding might be several miles out of place and it was difficult to be sure of the form, course, and depth of these canyons. Though some of them, notably the Hudson Canyon south-east of New York, the Congo Canyon off the coast of West Africa, and the Fosse de Cap Breton had been accepted, they aroused limited interest. The improved methods have revealed more fully the characteristics

of some of them and have added a large number of others not previously suspected. The new information stimulated fresh interest in these remarkable features but gave rise to a crop of speculations regarding their origin. An extensive literature has grown up around them, particularly in the United States of America.

Messrs. F. P. Shepard and C. N. Beard (*Geogr. Rev.* 28 (1938) 439–45) gave a list and a map of 102 canyons for which enough soundings were known to allow the construction of longitudinal profiles. The gradients at the head, middle, and each end of each are tabulated.

In addition some one hundred and twenty places are indicated where can-



yons are believed to exist, but sufficient information is not available to show that all these are typical canyons. There are numerous canyons off the east coast of the United States north of Chesapeake Bay, but they are apparently absent farther south. Many proved and many more doubtful canyons occur off the west coast of Central and North America from the region of the Panama Canal to the Canadian border. A few are believed to lie off the coast of Chile north of Santiago. The Mediterranean is credited with twelve which are accepted by these authors, and nearly twice as many doubtful ones. In addition to one accepted canyon off each of the east and west coasts of Africa, many others are indicated, as well as some off the south of the continent.

Numerous examples are given for the eastern coast of Asia, both near the mainland as well as near islands lying off the coast. Some are also represented on the east and west coasts of Australia. So far as is known they are absent from both the Arctic and the Antarctic, though this may be due to lack of soundings.

The authors remark that canyons appear to be absent from certain areas of the United States coast where there are sufficient soundings to have discovered them had they been present. These are areas which have an extremely gentle continental slope. If a correlation between the presence or absence of canyons and the inclination of the Continental Slope is verified by further investigations it may prove of the highest significance in relation to their origin.

More recently the results of the surveys by the U.S. Coast and Geodetic Survey along the Atlantic coast from the Georges Bank region to Norfolk, Virginia, have been beautifully reproduced by the Geological Society of America with a brief explanatory pamphlet by A. C. Veatch and Paul A. Smith (Special Paper No. 7 : "Atlantic submarine valleys of the United States and the Congo submarine valley, 1939"). Each of the charts was prepared in three forms: with soundings only, with soundings and contours (A), and "with contours and stream-lines only" (B). Charts A and B are printed on paper thin enough to fold and are issued with Special Paper No. 7. The charts showing soundings only are printed on heavy paper and have not been distributed, but may be purchased from the Director, U.S. Coast and Geodetic Survey, Washington, D.C., at 75 cents each. The charts are on the scale of 1 : 120,000. Certain shallow-water areas where dangers to navigation may exist were surveyed on scales of 1 : 40,000 and 1 : 80,000; these have not been issued. The soundings on them are so numerous that less than one-fifth of their number could be plotted on the scale of 1 : 120,000. The charts are accompanied by a coloured map (Plate 1) on the scale of 1/M of the north-eastern United States and the adjacent Continental Shelf and Slope, which was issued as a folder in the *Geogr. Review* for March 1939 with a brief explanation by P. A. Smith.

These charts are named and numbered as follows: I South-east of New York Bay including the Hudson Canyon (Coast Survey Chart 1316); II south-east of Delaware Bay including the Wilmington and Baltimore canyons (1317); III east of the entrance to Chesapeake Bay including the Washington and Norfolk canyons (1318); IV south of Georges Bank including the four canyons Lydonia, Oceanographer, Welker, and Hydrographer, which aroused such interest when these were discovered by echo-sounding a few years ago (Fig. 3 on p. 9, Special Paper 7); V the area on the shelf including the course of the Hudson Channel to the lip of the Hudson Canyon (number not stated). The area between charts I and IV was surveyed in 1938 and 1939, but the data were not available for publication when the remainder were issued. The information is however incorporated in a generalized form on the map (Plate 1). It is stated that there have been improvements in technique, in instruments, and in experience, so that charts I and V are of a higher quality than Chart IV, the others occupying an intermediate position. The difference is partly in the relative intensity of the soundings and partly in the plan of the survey. On Chart III lines of soundings running N.E.–S.W. and N.W.–S.E. were fixed by dead reckoning with occasional checks by radio-

acoustic ranging. The positions may therefore be in error by as much as 2 miles, though the profiles are correct.

It is found convenient to plot the soundings as the survey progresses. This enables the surveyors to judge whether an area has been adequately covered and to arrange for additional lines where desirable. The prepared plate of soundings is lithographed and printed. A print made in red on Bristol board backed by aluminium is used for preparing the contours, and finally another print is prepared on which are represented the courses of streams which are supposed to have caused the erosion of the canyons. The method of contouring is illustrated by reference to the region of the Wilmington and Baltimore submarine canyons. The first stage in the contouring is that of drawing "mechanical connections" at 50-fathom intervals between the sounding data. This is a purely mechanical process and involves no theory of the significance of the data. "These mechanical lines do not suggest any structural shapes or combination of structural shapes of a character akin to the well-known structural conditions of the coastal belt along, and inland from, the adjacent coast. Neither do they suggest great volcanic forms. *The sole remaining alternative is that there is here on the sea bottom a stream erosion topography*, and that the mechanical 'contours' have their unreasonable and contradictory shapes owing to the inevitable connection by this mechanical process, of hilltops or hillsides that happen to have the same level, without the representation of the intervening valleys. The problem, then, is to draw erosion forms having reasonably probable shapes which give full value to every one of the soundings made, and which at the same time are in accord with the topography known to exist on the sea bottom a short distance to the south, *and which are in agreement with the character of the topography that would be developed by stream erosion on a seaward-tilted peneplain underlain by soft, gently dipping Cretaceous and Tertiary strata*" (S.P. No. 7, p. 75. Italics are mine.—O.T.J.). This process is illustrated by Figs. 24–27. A comparison of Fig. 26, showing the mechanical connections only, with Fig. 27 showing the interpretation of the soundings in the published charts will give some idea of the radical differences between two methods of treating the same or nearly the same set of data.

It is important to bear the above statement in mind when the contours are discussed in the light of theories regarding the mode of origin of the canyons. For it is astonishing that a comparison was so readily made between these submarine features and those developed by stream erosion on the nearby coastal plain where the stream gradients "are only a few feet to the mile," whereas on the Continental Slope they "are as much as several hundred feet to the mile" (p. 74). Shepard and Beard (*G.R.* 28, p. 441) tabulate one hundred canyons according to their gradients at the head, middle, and end. At the heads seventy-three have a gradient exceeding 5 per cent. and twenty-one exceed 10 per cent. Even at the ends high gradients prevail; thirty-seven exceed 5 per cent., twenty-six lie between 5 and 10 per cent., while eleven slope at more than 10 per cent. Since some of these are on the continental slope of U.S.A., such gradients appear extraordinarily high for valleys carved by stream erosion in soft Cretaceous and Tertiary strata in a temperate climate. The gradients of the canyons from the Hudson to the Norfolk are

given in Special Paper No. 7. At the heads they range from 4·6 to 5·8 per cent.; in the middles from 2·4 to 4·8 per cent., and at the ends between 1000 and 1500 fathoms they are from 1·5 to 1·7 per cent.

Hitherto interest has centred mainly around the canyons, but the features of the Continental Slope are equally remarkable, and the topographic break between the shelf and the slope immediately arrests the eye: even more on the map than on the individual charts.

The Continental Shelf.—The very detailed soundings enable contour lines to be drawn every 5 fathoms. These bring out clearly the form of the sea floor and reveal three types of bottom: the submarine channels of the Hudson and the Delaware; the shelf outside these channels and lying roughly at less depth than 50 fathoms; and the region between the 50-fathom line and the break of slope which occurs near the 100-fathom line.

Within the Hudson Channel region elongated ridges and depressions are aligned in the general direction of the channel and are presumably due to scour by the river current. These begin to lose their trend and sharpness at about 40 fathoms, and there merge into the features of the shelf. Similar forms are displayed down to a depth of 20–25 fathoms along the Delaware Channel.

The larger part of the shelf is occupied by elongated ridges and channels and irregular mounds; their general trend varies but is on the whole rudely parallel to the coast. They resemble closely the shoals and deeps in the North Sea near the Thames Estuary. There is no doubt that they are produced by strong bottom scour. It is therefore unlikely that any of the finer sediments can accumulate and unless subsidence is going on no increase in the thickness of deposits on the shelf can take place. These conditions are comparable with those governing the formation of many shallow water deposits at various past geological periods. From the Hudson southwards and for some distance northwards the broken topography gives place at around 50 fathoms to a more even surface sloping gently towards the edge of the shelf. Occasionally broken topography lies within this belt, and the major canyons trench upon it. In the Hudson Channel region the contour lines of the outer shelf bend slightly inwards for a distance of about 60 miles, indicating a broad depression sloping evenly like the adjoining areas at similar depths. This belt is transitional between the current-swept shallower part of the shelf and another region which lies, or once lay, farther out to sea. It is probable that on it deposition is probably proceeding slowly, though interrupted from time to time by current scour.

Incidentally, there is no clear indication on the charts that the Hudson Canyon which trenches the 50-fathom line has any causal connection with the Hudson Channel which has all but lost its distinguishing features before reaching the canyon head. Of all the canyons mapped on the American coast this is the only one that shows any relation to an existing river valley, and it may be only a coincidence.

The Continental Slope.—There is no doubt that the resting-place for the finer constituents washed off the Continental Shelf is in the deeper waters,

which are less disturbed or are wholly unaffected by currents. The Continental Slope is therefore the region where these fine-grained deposits might be expected to accumulate; their coarser portions near the upper edge of the shelf and the finest lower down the slope and in the deep waters beyond its foot. This must be true not only for the present but also during the much more rapid deposition that must have occurred towards the close of the glacial period. Since in normal conditions the passage from the disturbed area on the coastal shelf to that where sedimentation is uninterrupted is gradual, there must result a continuous surface from the edge of the shelf to the deep region at the foot of the slope. The break of slope which now occurs near the top of the slope is therefore a wholly abnormal feature which calls for explanation. If it is borne in mind that consolidation of fine-grained deposits takes place slowly under the weight of the additional load of sediments, and that the more rapid the rate of deposition the less consolidated the material remains after the lapse of a given period of time, it will be realized that a condition may arrive where the growing deposit becomes unstable (O. T. Jones, "The consolidation of muddy sediments," *Geol. Mag.* 76 (1939) 170–2). Sliding or slumping will then occur at various parts of the slope in succession. This is the probable reason for the great topographic break. In the Continental Shelf and Slope area of the Eastern U.S.A., seismic investigations indicate that the seaward tilt of the peneplain on which the sediments lie has increased as sedimentation proceeded. This has also led to a condition of instability in the sedimentary mass.

Whatever the origin of the canyons, there is no doubt that the topography of the Continental Slope is due essentially to slumping. It is just as much due to sliding as is the landslip topography which for mile after mile has left a continuous scar near the brows of the old Red Sandstone valleys of the Black Mountains of Monmouthshire and Herefordshire. Recent studies on the slumped Lower Ludlow rocks of Denbighshire have revealed some of the characteristics of these great submarine slides (O. T. Jones, *Quart. Journ. Geol. Soc.* 93 (1937) 241–83D, and 95 (1940) 335–82). In that area slumping began in the north and the material slid southwards where it accumulated to a total depth of over 2000 feet. There is reason to infer that in the north the slumps occurred in relatively narrow channels or gutters, which increased rapidly in number southwards or down the original slope of deposition, and merged into an almost uninterrupted mass of slumped material. The sliding masses were capable of digging into the floors of the channels, and farther south there is reason to believe that erosion to a depth approaching 100 feet had occurred under the larger masses. The gutter topography of a series of submarine slides would present some analogy with stream channels, so that the presence of gutters and ridges revealed by soundings on the slope is no evidence that these features were produced by stream erosion.

Now the average gradient of the Continental Slope measured between the 100- and 1000-fathom countour lines (the average position of the latter) varies from about 4 to 8 per cent. Even at the lower figure sliding has occurred, so that a gradient of some 4 per cent. may be regarded as unstable. On the other hand there is a region immediately south of the Hudson Canyon where

both the 100- and the 200-fathom lines are smooth and the 300-fathom line is nearly so. Veatch and Smith regard this area as a depositional apron of the Hudson River. The gradient between the 100- and 200-fathom contours is about 2½ per cent., and that between the 200- and 300-fathom contours is between 4 and 5½ per cent. With these gradients sliding appears to have begun and is obvious below the 300-fathom line.

It would appear therefore that a slope of 2½ per cent. may be stable, but about 4 per cent. causes sliding. Once movement has started, the breaking down of the equilibrium between the grains of sediment and the included water results in a slurry which is more mobile than the undisturbed mass, and once flow has started the mud may continue to slide until its surface attains a very small gradient, and the larger the mass in motion the smaller the gradient at which it comes to rest.[1] The material which has slumped off the Continental Slope will have accumulated over a very wide area at the foot of the slope and extended towards the deeper parts of the ocean floor.

The canyons.—These valleys or trenches occur at irregular intervals on the Continental Slope from the Lydonia Canyon at the eastern end of the Georges Bank group to the Norfolk Canyon opposite Norfolk, Virginia. The larger trench deeply into the 100-fathom line and their heads reach in places up to the 50-fathom line. Similar but smaller trenches head down the slope at the 200- or 300-fathom line. If we count only those that clearly trench the 100-fathom line, there are seventeen in 460 miles; if smaller trenches are included the number is doubled. In addition there appear to be innumerable gullies or gutters. Thirteen canyons are named on the general map.

The gradient of all but the Hudson Canyon exceeds that of 4 per cent. at which the configuration of the Continental Slope shows clearly that sliding has occurred. With the doubtful exception of parts of the Hudson, if unconsolidated mud in quantity were poured into any of the existing canyons it would immediately flow out of them. The smaller trenches originating lower down the slope have even steeper gradients, since they indent the contours of a slope which itself exhibits clear evidence of slumping. Thus a small canyon west of Atlantic Canyon heading between 200 and 300 fathoms has a gradient of nearly 8 per cent. between 300 and 1000 fathoms; another west of Oceanographer Canyon has over 8 per cent. In general the Continental Slope and the furrows on it are steeper towards their upper limits and flatten downwards.

With the exception of an area near the lower parts of the Wilmington and Baltimore Canyons the grain of the smaller elevations and depressions is perpendicular to the trend of the slope, although this runs in places east and west and in others nearly north and south. Some of the canyon heads enter however at an oblique angle, notably the four southern. An attempt has been made to connect them with former mouths of one or other of the main rivers (Veatch and Smith, *op. cit., supra*, p. 43, Fig. 13). It is very doubtful however if there is any connection between the canyons and any existing river except possibly the Hudson. Out of over thirty canyons large and small it would be remarkable if none happened to lie in the course of a river channel.

[1] Arnold Heim: Über rezente und fossile subaquatische Rutschungen und deren lithologische Bedeutung (*Neu. Jahr. f. Mineralogie*, 1908, ii, p. 136).

In the southern part of the region where detailed soundings have been made the surveys have been carried to a depth of over 1500 fathoms. The elevation and depression type of topography characteristic of the higher parts of the Continental Slope prevails to this depth, but it is difficult to pick out the lower courses of the major canyons from among other irregularities on the slope which appear to have a similar trend. It would appear however that much of the exceptional trend which is displayed in this region is governed by the direction of the sounding traverses. In between many of these lines ridges and furrows are shown trending parallel to the traverses for which there does not appear to be any justification in the sounding data.

In some discussions much has been made of their winding character, branching forms, and numerous tributaries. The thing that catches the eye in a general view is however the remarkable straightness and trunk-like character of most: only two, Hudson and Norfolk, can be described as winding, and this only in their upper portions. Three of them, Wilmington, Baltimore, and Washington, show a remarkable change in direction approximately at the edge of the coastal shelf, and both the Washington and Norfolk are supposed to turn abruptly southwards into sub-parallel courses somewhat below the 1000-fathom contour. This curious behaviour is based on contours constructed on the supposition that these canyons are stream-eroded valleys.

Theories of the origins of the canyons.—The discovery of the canyons on Georges Bank, based on accurate soundings and positions, stimulated a large crop of theories in explanation. At a very early stage one particular theory was advocated by Shepard and others who were particularly concerned in these earlier investigations on the Atlantic coast of the United States. On this theory the canyons were developed by subaerial dissection by stream-erosion during a period when the shelf and the Continental Slope had been laid bare and a subsequent return of the sea submerged the topography produced by sub-aerial erosion. This theory has found favour also with the authors responsible for the contouring of the charts published with Special Paper No. 7. The contouring of these charts is mainly the work of the late A. C. Veatch and the system of contours is based on the idea that he had to deal with a topography developed under subaerial conditions.

Douglas Johnson, in 'The origin of submarine canyons' (New York: Columbia University Press, 1939), has recently published a critical review of the hypotheses put forward within the last half-century. They are classified into groups involving tectonic, subaerial, and subterranean origin. Many of these are of academic interest only or were evolved to explain special cases.

Discussion has until recently centred mainly around two opposed methods, subaerial stream erosion and subsequent submergence, and Daly's hypothesis of erosion by turbid streams of mud washed off the Continental Shelf while it was uncovered during the glacial period. Both involve the supposition that sea-level was lower than at present, but whereas Daly demands only a withdrawal of the sea to some 100 fathoms, the other theory requires a withdrawal to at least 1500 fathoms.

A. C. Veatch, from a study of the lower Congo basin and the Congo submarine canyon which presents many resemblances to the American canyons,

concludes that in Mousterian time "there was a recession of the Atlantic waters to a shore-line located 10,000 feet or more below the present sea-level, and the return of these waters to the present level less than 10,000 years ago " (p. 30).

Later it is stated more categorically that the "data on both sides of the ocean indicate that during the last erosion period the sea reached a point approximately 12,000 feet below its present level. Any explanation of these facts must account for a change of 12,000 feet, down and then up again, along a strip between our north-eastern Atlantic coast and the Congo, and in the very short period between the time—20,000 to 25,000 years ago—when the Wisconsin ice cleared the Mohawk outlet and the return of the sea to its present level about 5000 years ago " (p. 41).

One would have thought that the necessity of making this extravagant assumption about sea-level would have administered the *coup de grâce* to the theory of subaerial erosion. But, in one form or another the theory, in spite of its forbidding basic assumption, still has adherents.

Daly's theory was put forward in an attempt to supply some explanation less incredible than that of subaerial erosion and the enormous changes of sea-level which it demands.

More recently Douglas Johnson, having reviewed both Daly's and the subaerial theory, concluded that as there was so little support for either except as a remote working hypothesis, some other explanation was obviously called for. His new hypothesis assumes that water issues in powerful springs from the sediments which build up the coastal shelf and that the solvent effect of the spring water is so great that in time the rocks are dissolved or sapped and the spring migrates towards the land, leaving in its retreat the canyon.

We will now review the arguments for and against these three hypotheses; it is convenient to discuss them in the reverse order.

Johnson's hypothesis.—Others had already attributed certain canyons to discharge of rivers which had flowed through subterranean channels from the adjoining land to the Continental Slope, but the chief novelty claimed by Johnson for his hypothesis is that it attributes the formation of the canyon to solution and sapping of the canyon head by artesian waters emerging on the slope, not by the ordinary process of stream erosion, operating on the sea floor.

Stated summarily the hypothesis rests upon the proved experience that the deposits of the coastal plain of the U.S.A. from New Jersey to Florida contain water-bearing horizons which if tapped by boring yield artesian water; numerous reported instances in this area and other parts of the world of fresh-water springs breaking out under the sea at varying distances from the coast; the known capacity of water, particularly when charged with certain gases, of dissolving to some extent all rock-forming minerals; and the fact that certain box-canyons in the basalts of the Western United States and shallow trough-like valleys in Florida called "square heads" have been explained by the solvent and sapping action of powerful springs which issue at their heads.

Assuming that water-bearing horizons similar to those that underlie the coastal plain occur in the seaward continuation of those deposits under the

Continental Shelf, then it becomes highly probable that water may escape at various points of the slope as springs large or small. Since the majority of the known water-bearing horizons of the coastal plain are Cretaceous or Tertiary, whereas the superficial deposits of both the coastal plain and the shelf, as well as of parts of the slope, are Pleistocene or Recent, it is improbable that these water-bearing sediments outcrop directly on the slope. Springs fed from them may however reach the bottom of the sea by breaking through the overlying deposits, or the latter may in places slide off the face of the slope, thus laying bare one or more of these horizons. In order that springs may continue to flow it is necessary that there is sufficient head inland to overcome the greater density of sea water (about 1·025) and the frictional resistance of flow through the water-bearing sediments. There is no difficulty about securing on the present coastal plain the head necessary to overcome the sea-water density, but it requires a considerably greater head to force the inland fresh water over 100 miles to the slope.

If a spring breaks out on the Continental Slope, then according to the hypothesis a canyon will begin to develop. Material is removed in solution by the spring water, thus weakening the rocks and causing them to crumble and fall into the depression created at the spring.

The succeeding stages of canyon development are passed over rather lightly by Johnson. If however it be imagined that the spring has migrated some distance inward from the face of the slope, then the original partially consolidated sediments emerging on the slope have been replaced by a deposit which has crumbled down and fallen in from the sides. This material may well occupy in its disintegrated condition a larger volume than the original sediments which it replaces, and it is obviously important to find some means of removing some or all of it, as otherwise canyon development may cease. The water of the spring may be comparatively fresh and thus lighter than sea-water, when it will rise to the surface of the sea against the head wall of the incipient canyon; or it may be so impregnated with mineral matter removed in solution during its passage towards the shelf as to be denser than sea water, when it will flow down the slope. In the latter case only it may have power to transport broken-down material which cumbers the floor of the canyon. In the former case the only material that can be removed is by solution. It is unlikely that either of these processes will prove effective in keeping the canyon clear, and Johnson assumes that the weakened material which falls into the canyon will slide out at the canyon mouth. If spring water can sap the canyon head, and submarine sliding is effective in removing the material that falls in from the head and sides as the sapping proceeds, then there is practically no limit to the length of canyon that can be developed in time by these operations. Again, given sufficient time the hardness or insolubility of the rocks do not prevent extension of the canyon; they only slow down its rate of formation.

This hypothesis has several obvious merits; it accounts for canyons of various sizes along a given strip of Continental Slope; it also affords a possible explanation of the different levels at which they head on the slope, and it meets the possibility that some canyons on the coast of California may have been developed in granitic rocks, although the claim that this is so has not

been definitely confirmed. It also overcomes the objection that canyons are absent from parts of the coastal plain where the underlying deposits are probably similar to those farther north, where many examples occur. If for any reason the springs were not able to break through the deposits on the face of the Continental Slope no canyons could be produced.

It is however faced by several obvious difficulties, some of which have been foreseen by its author. First, the present coastal plain which receives the rainfall to feed the springs is of such low relief that it is doubtful if there is sufficient head to overcome frictional flow through the water-bearing formations to the face of the slope. It is possible however that water percolating into the more elevated surface of the Piedmont region may find its way into the lower part of the coastal plain deposits and thus provide the necessary head. It is not safe to argue as the author does that because water flows continuously from a well bored near the coast there was a constant flow of water seaward at that point before the well was made (p. 75). Secondly, there is no coastal plain north of the Georges Bank, and it is difficult to see how the hypothesis under existing conditions can account for the canyons of that area unless the springs are assumed to be fed from the crystalline rocks of Massachusetts some 250–300 miles away.

Thirdly, on any probable view of the structure of the coastal plain any water-bearing horizon slopes gently seaward, and its outcrop may be 10,000 feet or more below the surface of the sea. As the canyon head retreated the level of a spring at that horizon would presumably rise inland in conformity with the rise of the water-bearing stratum. Since the intake ends of these formations lie some distance inland from the shore it is difficult to see why in the first place the larger canyons all head at so nearly the same level on the coastal shelf, and in the second place why the canyons have a gradient which is many times greater than the probable slope of the water-bearing stratum which guided their headward migration. This difficulty is not touched on by Johnson. It is not however insuperable and a way out of it can be suggested. Since continued canyon development depends on the removal of the material which falls on to the floor it is not improbable that the gradient of the floor of the canyon is just that which is necessary for submarine sliding. Below the floor there may be a fill of weakened material which has not slid out because of insufficient slope. In these conditions weakening of the rocks about the outlet of the spring below the fill can occur only between the canyon head and the fill, but above the level of the floor collapse of the head and side walls of the canyon may take place. This is a serious difficulty which requires some further explanation. Alternatively, headward erosion beginning at a lower level may tap other springs at a higher level, which may continue the process after a spring at a lower level has become ineffective. This alternative would appear to leave a good deal to chance.

Fourthly, it may be asked whether fresh water which had been in contact with the minerals of a water-bearing formation during its long passage from the surface to the Continental Slope would not be already saturated and incapable of dissolving anything more when it emerged on the sea floor; and whether the contact of water of high mineral saturation with sea water would be more likely to promote further solution or to lead to precipitation. The

effectiveness of spring action would appear to depend upon the answer to these questions.

Johnson points out that the difficulty of providing a gathering ground at a sufficiently high level would be less in past times, such as the late Cretaceous and Tertiary, when the deposits of the coastal plain extended widely beyond their present margin at the fall-line on to the higher regions of the Piedmont and the Appalachians. There would then be an ample hydraulic gradient for the water to reach the Continental Slope, wherever it may have been. Canyon development might therefore have been most active in earlier geological periods and may now be in a waning phase, and the present canyons mainly or wholly an inheritance from earlier conditions.

The appeal to former conditions only partly meets the difficulty of the Georges Bank group. Since however there are remnants of Cretaceous and Tertiary rocks on Long Island and Miocene deposits occur on Martha's Vineyard, it is possible that an extensive coastal plain once existed off the Massachusetts coast, which reproduced at that time conditions similar to those that now prevail from Long Island southwards. If so, the Georges Bank canyons ceased to develop a long time ago and have remained more or less in their present condition since some part of the Tertiary period. Gradual collapse of their sides and head should have reduced these slopes more than in canyons farther south, whose development may have continued to more recent times, perhaps even to the present. The soundings do not appear to support such a conclusion, though a distinction has been drawn between the Georges Bank Canyon and those off Maryland, from differences in the rock samples obtained by dredging across the canyon.

Daly's hypothesis rests on two main postulates: that during the glacial period a large volume of water was locked up in ice and snow at the expense of the volume of water in the sea, so that the coastal shelves of the world were laid bare for a considerable distance from the former shores; and, that sea water rendered very turbid by waves on the exposed coastal shelves sank through the clearer sea water over the Continental Slope and eroded the surface of the slope.

The evidence for the first postulate is discussed at length in connection with Daly's glacial control theory. The lowering generally considered possible is round about 300 feet, which would lay bare rather more than half the existing shelf; but much larger estimates have been put forward. The formation of the canyons depends however much more upon the validity of the second postulate.

That water of greater density from matter in solution or suspension will sink in water of less density may be accepted, but this does not necessarily involve belief that a current set up in this way can cause erosion, either general or local, of the surface over which it flows.

Johnson, in the discussion of Daly's views, finds that much confusion has been caused by the analogy drawn by Daly between the canyons and sub-lacustrine ravines that occur near the mouth of the Rhine in Lake Constance and that of the Rhone in the Lake of Geneva. In both these lakes the silt-laden waters sink suddenly and violently out of sight below the clear warmer

surface waters of the lakes. The inference drawn by Daly was that if these silt-laden waters could excavate sublacustrine trenches some 50–70 metres deep such as occur in these lakes, it was not unreasonable to suppose that turbid currents under favourable conditions might erode deeper and longer trenches comparable with the submarine canyons. Johnson shows however that Forel and others who had investigated the sublacustrine ravines had come to the conclusion that they owed little if anything to erosion but were due in the main to the deposition of levées of silt in the quieter waters alongside the strong silt-laden current flowing near or on the bottom, and that the floor of the ravines was at approximately the same level in the Lake of Geneva as the floor of the lake beyond the foot of the levées and little, if any, lower in the Lake of Constance. Johnson further points out that in other lakes silt-laden waters sink violently below the surface, yet no sublacustrine ravines have been produced in them. The theory is faced by other difficulties. It is not obvious why the muddy waters gathered into narrow threads at certain points on the shelf; nor how a continuous supply of muddy water was maintained after the waves had done their worst in stirring up material when the shelf became exposed. Furthermore it is unlikely that there ever was much mud on the shelf in pre-glacial times, any more than at present. But the main difficulty is the absence of evidence that such currents if they could be produced would have the necessary eroding power.

There remains the hypothesis of subaerial erosion during the emergence of the Continental Slope: commonly associated with the name of F. P. Shepard, though it is accepted by others. It rests on three assumptions: that there is no alternative (Special Paper, p. 75); that the winding character, branching forms, tributaries, cross sections, and longitudinal gradients of the canyons are similar to stream-eroded valleys on land; and that the features of the dissected Continental Slope are similar to certain gullied areas in the Western United States. Each is open to criticism; but the main difficulty in this hypothesis is its basic requirement that a change in the relative levels of land and sea has taken place of some 12,000 feet in both directions in comparatively recent geological time.

It has been suggested that the canyons are much older features than their association with the sediments of the coastal shelf would suggest and have been kept open in various ways (also by Shepard); or that the exposure did not involve a general lowering of all the ocean, but was due to warping of the coastal regions (advocated by A. C. Veatch and more recently by A. L. du Toit); or that the sea was much lower during the glacial period than is contemplated by Daly (this also by Shepard). There is nothing to choose in point of extravagance between the second and third suggestions.

It is more important to examine the claim that the submarine topography of the Continental Slope simulates stream erosion so closely that no other origin can be considered possible.

The soundings reveal clearly very considerable elevations and depressions along numerous traverses, especially those run nearly parallel to the edge of the shelf. Each of a large number of parallel traverses shows very similar

features. In the best traverses of the Coast and Geodetic Survey the soundings are shown about five to a statute mile; on others they may be about twice this distance apart. The traverse lines are however spaced, in general, at intervals varying from something under 1 to 3 miles and occasionally 5 to 6 miles. One way of showing the soundings along a traverse is by drawing a vertical section along the line, joining individual points by straight lines or by smoothed curves which take account of neighbouring soundings. While the smoothed curves may not be accurate in detail this method probably gives a truer idea of the form of the surface than if the points are joined by straight lines.

The method most commonly employed on land is that of contouring; if any doubt exists about the run of a given contour-line it can be checked by inspection of the ground. When the method is employed for representing soundings, visual control is impossible; the only check is by running fresh traverses, which is difficult, as even with the most painstaking care there would be some uncertainty in the relative horizontal position of a fresh line run later.

On one of the charts (IIIA) which was contoured by A. C. Veatch, the Coast and Geodetic Survey ran a line of soundings about 20 miles long obliquely across the deeper part of the Continental Slope. It was admittedly a difficult region to contour owing to the few traverses in the area. The contours on the chart give a very different expression to the topography from that revealed by the new soundings, the departure being as much as 120 fathoms in places. I tried the experiment of mechanically contouring a part of the chart showing soundings and contours round about this area but not the line of new soundings which is on another chart (IIIB). The topography that I obtained is much nearer that revealed by the new soundings and the greatest discrepancy is 60 fathoms.

However, to picture a vast mass of soundings, contouring is the most convenient method available. Where the data are numerous a contour is drawn in such a way that it falls in the most probable place, taking account in an approximate way of the probable character of the slope by inspection of the neighbouring soundings. But in general it is considered sufficient, with points fairly close together, to assume that the surface between two soundings slopes uniformly.

Copies of the charts recently issued by the American Geological Society, with soundings only, are not yet available in this country; but I have tried contouring a comparable series of soundings on the Pacific Coast which have likewise been interpreted by contours on the basis that the topography was due to subaerial erosion. It is instructive to find that the valley and ridge forms suggested by one line of soundings is not shown clearly, if at all, by the next parallel line. To join up lines to form continuous valley sides seems very hazardous, and one cannot have any confidence in the result. Certain broad features representing some of the deeper valleys are obvious, but in general smaller details are subject to a large personal error. An attempt to represent in visual form an invisible surface of necessity involves some degree of interpretation and assumption. Some forms of interpretation may be relatively harmless; others may offer a definite hindrance to a true appreciation of the soundings.

In some respects it is unfortunate that the recent charts have been contoured in the belief that the topography is the result of stream erosion, instead of drawing the simplest form of contour lines that conformed with the data, regardless whether the lines appeared consistent or not. The result of Veatch's contouring is a pretty picture, but it is quite certain that the data will not support more than a fraction of the smaller details shown on these charts. In particular the majority of the short "tributaries" which abound on the charts would disappear.

Still more unfortunately another series of charts (Series B) has been issued showing in blue the contours and in brown the courses of streams which are supposed to have flowed down these valleys. So long as these stream-lines are looked upon merely as a convenient means of picking out "valleys" from "ridges" on the A Series of charts no great harm will result. It is very difficult however to retain an open mind regarding the significance of a mass of sounding data if they are overlaid by a pictorial representation based on some idea which may have been wrongly conceived. It should be emphasized that the contour lines on these charts cannot be appealed to in support of the theory that the features were produced by subaerial erosion, since the contours have been constructed expressly on that hypothesis. But one may fear that many people have been fascinated by these contours into a belief in the subaerial theory.

The authors claim that there is no alternative explanation of the topography. Since then however Johnson has put forward one hypothesis of which an essential feature is the sliding of material out of the canyons; the same might occur at many places on the Continental Slope. Daly has propounded another which involves erosion by turbid currents sweeping down the slope. It is not clear also that ordinary slumping would not give rise to a similar series of forms. In all these cases channels would be aligned approximately at right-angles to the trend of the slope. Unless therefore the channels exhibit some characteristic in which they differ from those produced by other means, and also agree closely with true stream-eroded channels, the statement that there is no alternative explanation of these forms cannot be accepted.

It is usually claimed that they agree with stream-cut valleys in their winding courses, their branching tributaries, their cross-sections, and their longitudinal gradients. There is no obvious reason why channels developed either on Johnson's or Daly's hypotheses or even by slumping should not possess the first three characteristics; the longitudinal profiles might however be expected to show differences characteristic of the particular mode of formation.

Now it is acknowledged that "the gradients of the submarine valleys between Georges Bank and Cape Hatteras are, without exception, remarkably steep; few features of the same magnitude are found in subaerial canyons" (Special Paper No. 7, p. 15). The figures on pages 16 and 18 show that the longitudinal profiles of the submarine channels are in general much higher than the most favourable cases of subaerial valleys. On the other hand they agree admirably with the sort of gradients to be expected if the material in them has been discharged by mud flowing or slumping. A mud flow like any other flowing body requires a higher gradient the smaller the mass in motion.

If a mud flow began at or near the upper end of one of these valleys its mass would increase as in its travel it picked up further mud from the floor and sides of the channel. The larger the mass became the lower the gradient that was necessary for continued motion, so that the floor of the valley would have a characteristic concave profile.

The fact that subaerial erosion as an explanation of the canyons has received any consideration at all is due to the too ready acceptance of statements that the characteristics of the canyons and of the Continental Slope are similar to those of valleys and gullies produced by subaerial erosion. This claim is not supported by an unprejudiced examination of the submarine forms revealed by the soundings and should not therefore be allowed to influence the judgment in considering other interpretations of the data.

It is in no ungenerous spirit that the above criticisms are offered of the beautiful series of charts published by the Geological Society of America. The authors of the charts realized that others might form a different opinion of the origin of the submarine features. One hopes that sufficient copies of the charts with the soundings alone will be made available in this country, so that others who hold different views may test them on the original data. Geologists and geographers owe a debt of gratitude to the U.S. Coast and Geodetic Survey for the services they have rendered in acquiring at considerable expense this invaluable series of records of one of the most interesting areas of the sea floor, and to the Geological Society for having made them available so promptly.

Some drawings of contours and profiles which should have illustrated this paper could not be completed in time. They will be published in a later number of the volume.—ED. *G.J.*

DISCUSSION

Before the paper the CHAIRMAN (Colonel Sir GERALD LENOX-CONYNGHAM) said: I am in a particularly good position to introduce the lecturer because I have known Professor Jones ever since he came to Cambridge as Woodwardian Professor of Geology, and can assure you that he speaks with the authority that emanates from wide and accurate knowledge.

Oceanic shelves are curious features of submarine topography. Their origin and nature has been much debated, but only within fairly recent times has it been possible to get any real knowledge of them, and even now the investigation is difficult. It would greatly advance our knowledge of the history of the Earth's surface if we knew what the shelves were made of, how they were formed, and what is happening to them. Professor Jones will tell us what knowledge has been acquired and the methods which have proved tolerably successful in ascertaining their nature.

Professor Jones then read the paper printed above, and a discussion followed.

The CHAIRMAN: We have listened to an exceedingly interesting account of the continental shelves and slopes, their form, and the materials of which they are composed. Towards the latter part of his paper Professor Jones gave an account of the various attempts that have been made to explain the formation of the submarine canyons. I do not know which of them I think the most plausible. All the explanations seem to be fraught with doubt and difficulty. He told us that

some investigation of continental shelves had been carried out on this side of the Atlantic by Dr. Bullard, and I can say a little about that work, for Dr. Bullard belongs to the Department of Geodesy and Geophysics at Cambridge. In 1938 the Hydrographer of the Admiralty, Vice-Admiral Edgell, put a fine survey ship, H.M.S. *Jason*, at our disposal in order that the thickness of the sediments covering the floor of hard crystalline rock should be determined by the seismic method at various points between the shore and the edge of the continental shelf. Professor Jones did not mention that at the same time the Navy had put a submarine, H.M.S. *Narwhal*, at our disposal for making gravity determinations over the same area and farther afield, by the method invented by Dr. Vening Meinesz of the Netherlands Geodetic Service. Dr. Vening Meinesz had lent us his own apparatus and it had been erected in the *Narwhal* with all the accessories that were required. Trial observations had been made near the coast of Cornwall to see that everything was in order and the *Narwhal* had actually moved out to the edge of the continental shelf, when she was recalled because the international situation was considered too serious for the vessel to remain away from her normal station. This was a grievous disappointment, but some useful experience had been gained. One conclusion was that it would be better to have two small ships, rather than one large, when carrying out the seismic investigations. If there is only one ship, then a boat has to be lowered for each experiment and sent to drop the explosives, while the ship carries the seismographs and the recording instruments. Unless the weather is very good the lowering of the boat is troublesome and even dangerous, and it was seen that to have two separate ships would be very advantageous, one to carry the recording instruments, etc., and the other to carry and lay the explosives. In the following year therefore, that is to say in June 1939, we hired two Brixham trawlers, and Dr. Bullard did some very valuable work from them.

The gravity work which was to have been carried out from the submarine was in charge of Mr. B. C. Browne, also of the Department of Geodesy and Geophysics. Both cruises made for the seismic work were very successful: each lasted about a fortnight. I am sure the gravity work would have been equally successful if the international situation had not stopped it.

Dr. E. B. BAILEY: In this difficult problem of submarine canyons the explanation that appeals most to me is that of submarine streams that owe their excess density to turbidity; and I think that very possibly the turbidity in question has been caused on occasion by an earthquake. In the case of an earthquake affecting the bottom of an ocean and making the water there extremely muddy and sandy, submarine streams might result, coursing down slopes and carving out valleys. The subject as a whole is extremely difficult, and I do not want in any way to suggest that that is the true explanation. It is only one that appeals to me most.

Professor E. G. R. TAYLOR: I do not wish to draw red herrings across the trail, but I should like Professor Jones to say whether he looks upon the slope of older crystalline rock as going continuously from the Piedmont region to the depths of the ocean; does he look upon that as the original slope, or would he take it as an ancient peneplain thrust down by the weight of the wedge of post-tertiary sedimentary material. Am I right in gathering that these wedges of sedimentary rock are, in a sense, like a vast delta, so that in front they have naturally a steep unstable slope? If so, one is puzzled as to why they should be of such different widths at different parts of the globe. Dr. Bullard's experiments off the Scilly Isles were very few; does Professor Jones think that, as a result of the experiments made off the coastal plain of the United States alone, where sub-aerial conditions are peculiar, it can be inferred that con-

tinental shelves in general have the appearance of those of the Eastern United States?

Professor JONES: There is something I might have said which is rather in favour of Professor Douglas Johnson's view and also, possibly, in favour of Dr. Bailey's view. The sediments when they accumulate are very full of water, and when they are finally converted into rocks all that water has been removed. When sediments accumulate fairly quickly the water in the lower layer of sediment, when it is covered over with clay, cannot get away fast enough; the pressure of the contained water is considerably higher than that of the bathymetric pressure. As a result of an earthquake shock the relation between particles and the water they contain is disturbed, but it is not so easy to see how the water could ever flow; and these canyons, as they are called, would have to flow. I feel practically certain that some of them must be due to mud flowing, whether by earthquake or otherwise.

In reply to Professor Taylor, so far as we know at present the warping down of the hard rocks seems to continue and has already approached such a depth that it is comparable with the floor of the sea. So far, there is no reason to suppose that there has been any change in the character of the rocks. In other words, the hard floor under the shelves is the continuation of the Piedmont which has been steadily subsiding (while the middle Piedmont is rising), allowing accumulation of sediments.

Dr. N. E. ODELL: Although Professor Douglas Johnson's theory is very attractive, I think in certain respects it is almost too good to be true! Moreover we must not forget the fact that the later work accomplished by F. P. Shepard and H. C. Stetson in the United States has shown that some of the canyons are definitely formed in hard rock and even in solid granite. They claim that there are about fourteen canyons on the west coast of North America, and two on the east coast, which have been clearly excavated in hard rock.

In one of his papers published in the *Proceedings* of the National Academy of Sciences, Washington, 22, 1936, Shepard shows by diagrams and sketches that these submarine channels clearly conform in a most extraordinary manner to those of the branching, fluviatile type, and therefore must have been due to sub-aerial action. They are quite different from the small channels and depressions formed definitely by submarine current scour.

F. P. Shepard contributed to the symposium at the XVIIth International Geological Congress held in Moscow in 1937, on the "Geology of the Arctic regions of Eurasia," and his contribution entitled "Polar ice-caps related to submarine canyons" was taken up very seriously by the Russian geologists, all of whom, I may say, hold the theory that the Pleistocene Ice Cap was of very much greater extent than ordinarily supposed. From evidence gleaned in Russia and Siberia of recent years, apparently the Pleistocene Ice Cap, according to Russian geologists, extended down as far as latitude 60°, about the latitude of Leningrad, and a long way east into Siberia. They also think that it may have covered the greater part of the Arctic basin. I know that to orthodox ears this sounds improbable, but anyhow if the ice cap were approximately of those dimensions we should have the sea-level lowered by something like 6000 feet. This would provide, of course, the conditions necessary for the sub-aerial erosion of these channels, and moreover meet the much-disputed coral island requirements. I know there are certain criticisms which may be levelled against that idea, particularly perhaps the isostatic evidence seems to be rather against it. However this evidence, as displayed by raised beaches in some parts of the Arctic, is often conflicting. For instance, I remember seeing some years ago that the terraces and raised beaches along the fjords of Spitsbergen were not

level but warped, and therefore indicative probably of only local isostatic "rebound" following the waning of the Inland and Highland Ice. W. G. V. Balchin has recently (1938) made measurements of these interesting occurrences but widespread data must be collected before we can draw any reliable conclusions as to isostatic effects over the whole Arctic basin.

Professor JONES: Mr. Odell's point was that the shelves might have been sloped and the water withdrawn to a much greater extent in the Pleistocene period if the ice cap was vastly greater than is commonly believed. Professor Daly developed the theory of the withdrawal of the water to the ice cap to a very full extent. That being his pet theory he naturally would put it forward in the most plausible way. He thought the water of the ocean might be lowered by 300 or 400 feet in that way, which is about a thirtieth part of that which is required. It seems to me that the extension of the ice cap and its increase in thickness to any considerable degree would have such extraordinary consequences on the Arctic basin that there ought to be more signs of it. All round Eastern Siberia there are beautiful terraces of comparatively recent origin which may go to 300 feet. If the ice cap had been of the extent the Russian geologists claim, I should have thought the submergence under that load would have been far greater, not only greater on account of thickness, but because it increases greatly with its size.

The CHAIRMAN: My only remaining duty is to thank the lecturer for the admirable account he has given of such a great advance in the methods by which submarine features can be studied. The echo-sounding method is becoming year by year more perfect. If you have sections of the sea-bottom on a series of lines which it is possible to make reasonably parallel, then you get the form of the floor without having to determine your position so frequently.

Though the technique of the seismic method is difficult, good progress has been made there also; Dr. Maurice Ewing in America and Dr. Bullard in this country have mastered these methods. I have no doubt that in a relatively short time it will become possible to investigate submarine features with great thoroughness; to map their shapes and find out what they are made of. The question of what is actually happening to them now will not be so easy to answer. You will join me in thanking Professor Jones for his exceedingly interesting discourse.

THE VOLCANIC ZONE OF TARAWERA, NEW ZEALAND

ALAN BROWNE

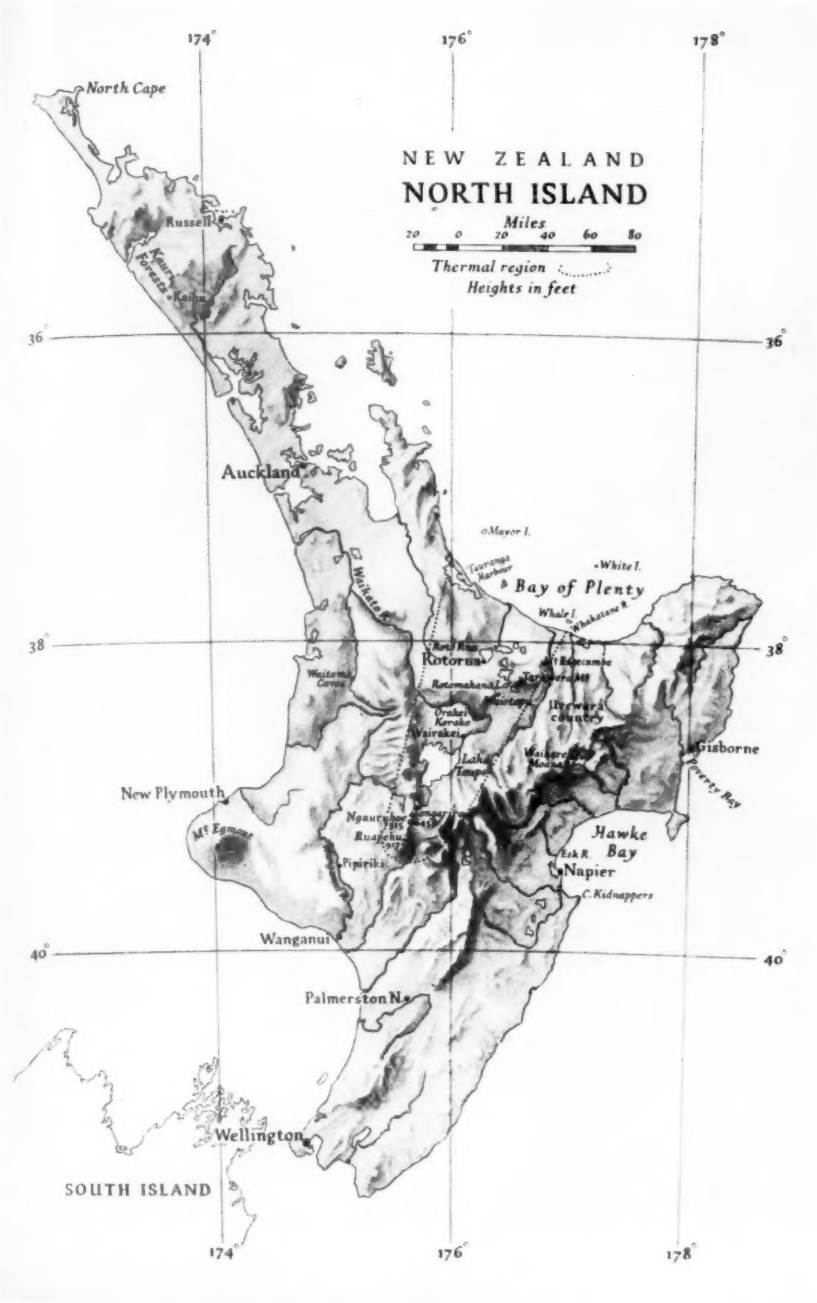
Meeting of the Society, 11 December 1939

WHILE signs of volcanic, thermal, and earthquake activity are found throughout practically the whole of New Zealand, by far the more active and visible evidence is in the North Island. Its main area is shown on the map, roughly in the shape of a narrow wedge whose blunted apex includes Lake Taupo and the group of volcanic mountains: Ngauruhoe (7515 feet), still active; Tongariro (6400 feet), with its Ketetahi spring; and Ruapehu (9175 feet), the latter the highest mountain in the North Island, with a hot lake in its snow-bound crater. From here the sides of the wedge run approximately north-east for 100 miles to the Bay of Plenty, where they touch the coast at Tauranga Harbour and the mouth of the Whakatane River respectively. The whole of this area is an elevated pumice plateau, 1000–1500 feet above sea-level, dotted with numerous large lakes, extinct volcanic cones, and hot springs. Activity is further continued in the sea-bed of the Bay of Plenty between the above-mentioned points; in Whale Island, with its hot springs; Mayor Island, with hot springs and a shining, black, obsidian-lined, extinct crater 5 miles in circumference; and White Island, an active volcano in the solfatara stage with warm water-filled crater half a mile in diameter, where, with hot sulphuric acid springs, is found hydrochloric acid of remarkable strength.

A little to the north of the centre of this belt of thermal activity, and alongside the lake from which it takes its name, is the town of Rotorua (3000 inhabitants) surrounded by and built amongst—one might almost say built on top of—hundreds of geysers, boiling springs, hot mud volcanoes, fumaroles, steaming lakes, and silica terraces. The many therapeutic waters and well-appointed bath houses of Rotorua are known to visitors from many countries.

South-east of Rotorua and at a distance of between 10 and 17 miles, in the heart of the thermal belt, lies a group of mountains, lakes, and valleys, which some fifty-four years ago were the scene of volcanic and thermal upheaval of a magnitude never even remotely approached in Australia or New Zealand during the last five or six hundred years.

Appreciation of the present topography and general appearance of the district as portrayed by the accompanying photographs is hardly possible without previous description of the country prior to the convulsions which so drastically reshaped it. Running from north-east to south-west was a mountain group whose three summits known to the Maoris as Wahanga, Ruawahia, and Tarawera, formed a rough, rocky, and much-crevassed plateau 3 miles long by half a mile in width, covered with large angular fragments of trachyte, broken and split up as though by frost. Although undoubtedly of volcanic origin, it seems reasonable to conclude from the state of the rocks and from the dense native forests that clothed the lower slopes, that no eruption of any size had taken place for many hundreds of years. The statement of the Maoris that it had never been known to erupt since they came to New Zealand


NEW ZEALAND
NORTH ISLAND
Miles
20 0 20 40 60 80
Thermal region
Heights in feet
174°
176°
178°
36°
38°
40°
North Cape
Russell
Kauri Forests
Kaitaia
Auckland
Mayor I.
White I.
Tauranga Harbour
Bay of Plenty
Whale I.
Whakatane R.
Waikato R.
Rotorua
Waiotapu Caves
Rotomahana L.
Mt Edgecumbe
Tarawera
Tarawera Mts
Orakei Korako
Wairakei
Huiarau country
Lake Taupo
Waikare Moana
Gisborne
Poverty Bay
New Plymouth
Mt Egmont
Ngauruhoe
Tongariro
Ruapehu
Pipiriki
Hawke Bay
Esk R.
Napier
C. Kidnappers
Wanganui
Palmerston N.
Wellington
SOUTH ISLAND

The White Terrace, Rotomahana, destroyed 10 June 1886

is borne out by the fact that the giant *totara* trees (hardwood), many of them more than 8 feet in diameter, must have taken at least five hundred years to reach maturity on such inhospitable ground.

Tarawera, the name now loosely given to the whole of the range, although in fact only the great south-westerly buttress, was then void of all forest and was *tapu*, sacred, to the Maoris, being for generations the burial place of their chieftains, whom they would never have buried on any ground they thought liable to disturbances. From the base of its precipitous, rocky, north-westerly cliffs Lake Tarawera (1000 feet above sea-level) stretched some 7 miles to the north and north-west, having on its shores several Maori villages: Te Ariki, where fruit and vegetables were grown in great quantities, and Moura on the tip of the most prominent peninsula. Seven miles across the lake at its most westerly extremity was the picturesque township of Te Wairoa, with its Maori settlement, English missions, ivy-covered church and church schools, hotels, and an old mill for grinding the wheat and maize which was grown plentifully by the Maoris in this then fertile district.

Continuing the line of the mountains in a south-westerly direction, and immediately at their foot, there were several small lakes including Rotomahana. This was then a small warm-to-hot lake of about 284 acres and a depth of 32 feet, and having two islands, Puai and Pukura, which were inhabited by the Maoris. The lake was raupó-fringed and native wildfowl abounded. On its north shore was the famous white terrace known to the natives as Tarata, meaning tattooing, on account of the very fine tracery of the silica terraces. This terrace covered an area of $7\frac{1}{2}$ acres and measured 800 feet from the lake side to the summit. To the west were the equally famous pink terraces, Otukapuarangi, meaning Cloud of Heaven.

At 2 a.m. on 10 June 1886 the whole range of Wahanga, Ruawahia, and Tarawera burst asunder. So far as is known, there was no preliminary warning. Incandescent rocks and ash were thrown into the sky to a height of 44,700 feet, as measured by Vickerman of the Survey Department, at Auckland, from which city, 140 miles away, the conflagration was clearly visible. Sounds were recorded as far north as the Bay of Islands, 220 miles away, and as far south as Christchurch in South Island, 420 miles. For thirty hours there was darkness, and it is estimated that in that time over a cubic mile, say 6000 million cubic yards, of rock and ash was ejected from this chasm alone. The vegetation, farming, and grazing was spoiled over an area of 1500 square miles, while over 5700 square miles received a deposit of rock, ash, and dust. The fissure through the mountain continued nearly in a straight line for a total distance of $8\frac{3}{4}$ miles, running on a true bearing of 238° from the north end of Wahanga to Lake Okaro. To the south-west it continued in earthquake cracks for some miles farther.

Immediately following this mountain eruption the rift continued south-westerly, the whole valley containing lake, pink and white terraces, islands, and people, was thrown to an immense height. Columns of steam to 14,000 feet were seen and measured from Rotorua, 17 miles away. It is estimated from the resulting chasm, whose maximum width was more than $1\frac{1}{2}$ miles, a further 600 million cubic yards of rock and mud were ejected and hurled on to the surrounding country. In the villages of Te Ariki and Moura about one

hundred Maoris were buried under ash, rock, and mud. For seven years there was no lake in the chasm where previously had been Rotomahana; instead were hundreds of great mud volcanoes and geysers. At the end of seven years boiling water began to fill this chasm till it overflowed, forming the present Rotomahana.

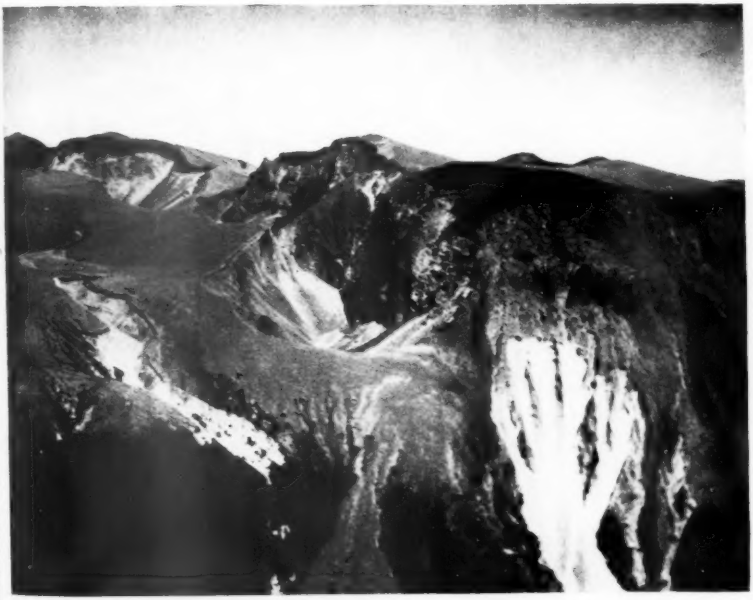
In the year 1900 Waimangu (Black Water) first began to erupt, throwing huge columns of water and great rocks to a height of between 700 and 1500 feet. On Sunday, 31 August 1903, four people were killed by the boiling water ejected. Immediately south and alongside Waimangu was an area of hundreds of geysers, springs, and mud volcanoes, known from the issuing sounds as Frying-pan Flat. At 6 a.m. on 1 April 1917 this flat completely blew up, wrecking the accommodation house half a mile away and causing many deaths. Explosions continued for several days and in three weeks it began to fill with water. Several weeks later it was completely filled with steaming water, presenting its present appearance, and being known now as Frying-pan Lake. On its north-west shore are precipitous, steaming cliffs, known as Gibraltar.

When Tarawera was first visited after the eruption of 1886 it was found that the great fissure consisted in reality of a series of craters in line, separated by unbroken harder ridges of rock. The average width of this fissure across the mountain is about 200 yards; the greatest depth was some 900 feet, towards the north end, that is between Ruawahia and Wahanga, where molten rocks and scoria were ejected. No lava was visible anywhere, though much may be at the bottom of the fissure, now deeply covered with fallen scoria and rock. For several weeks after the eruption steam was seen to be issuing from the vents, though for many years now there has been no sign of activity at all. Strong smells as of muriatic acid, iodine, and of burning were noticed for some time afterwards.

The whole appearance of the mountain now is one of grey ash and dust deeply furrowed by the rains. Practically the whole of the original forest has been completely wiped out. The twisted trunks of the *totara* trees, 8 feet in thickness, remain as evidence of the blast that accompanied the eruption. Patches of low native scrub and *tutu*, whose leaves are poisonous to cattle, are now gaining a foothold on the lower slopes. In contrast with the barren greyness of the summit, the red burnt rocks, especially of the lips of the fissure, stand out vividly. No complete vent is now visible anywhere in the fissures; they have been partly filled in by sliding and falling scoria which modifies the sheerness of the very precipitous sides. The general colour of the rocks in the fissure is blackish and dark red from the burning, interspersed with long streaks and patches of lighter, almost buff, stretches of scoria: presumably the colour of much of the original rock. The clearer yellow of the stones is due to ferric chloride.

The area destroyed by the eruption is still almost uninhabited, but one may see it in a day from Rotorua, driving to a point near the Southern Crater, taking the track past Frying-pan Flat to Rotomahana, a boat on the lake, the track across to Lake Tarawera, and launch to Te Wairoa. It is a very rough walk up the mountain over the loose scoria to the chasm and the craters.

1. The rift through Ruawahia and Wahanga, looking north-east



2. The rift through Wahanga and Ruawahia, looking west

3. Summit of Tarawera and Rotomahana, looking south-west

4. Lakes Rotomahana, Tarawera, Rotorua, looking north-west

The air photographs were taken on two flights from Rotorua at the end of 1937, with an Etui camera $3^1/_4 \times 2^1/_4$. It will be convenient to describe them from north-east to south-west along the line of the rift. When it is necessary to locate a point the distance in inches from the left hand and the lower edge will be given.

No. 1 is taken from over the rift near the summit of Ruawahia, looking about north-east by east over the gap between it and Wahanga and along the eastern edge of the latter mass, which has been sliced down by the rifting. The broken cone of Mount Edgecumbe (Putouaki, 2946 feet) is away to the right, and the dark range of Haroharo (summit 2529 feet) in the middle distance to the left. In the distance is the Bay of Plenty and Whale Island. The white mark at 3.2,1.5 seems to be the secondary rift seen in No. 2.

No. 2 is taken from a point a little to the east of the rift and beyond the last face of the rift in No. 1, looking about west, obliquely across the rift. The white patch in No. 1 at 3.2,1.5 seems to be near the upper end of the secondary rift to the left of No. 2. The dark pointed crest of the last face in No. 1 seems to be the dark crest-line at 2.8,2.5 in No. 2, and all the detail to the right and below the latter is just round the corner in No. 1. The summit of Wahanga is at 2.2,2.7 and of Ruawahia at 0.7,2.7. From the accounts of distant observers it would seem that the eruption of 10 June 1886 began somewhere about the deep crater in the centre of this picture, and that the cleft opened gradually towards the left through Ruawahia and Tarawera. The bridges of hard rock which were left standing as the rift opened are well shown in these two pictures. The craters threw up great quantities of red-hot rocks and dust, but no lava.

No. 7 looks down into the chasm below the summit of Ruawahia, shown at the top of No. 2. Bulletin No. 37 of the N.Z. Geological Survey (1937) says on p. 83 that the fissure is a chain of twelve elongated oblong craters about 300 yards wide and about 400 feet deep. Tarawera chasm, of which we have no near photograph, is the longest, and the others range from 400 to 700 yards. They are separated by narrow bridges of solid rock. The only bridge of any width is the one a quarter of a mile wide between Tarawera chasm and the Ruawahia craters. The other bridges scarcely if at all reach the surface. Between Tarawera Chasm and Ruawahia trig. are six craters in line extending along the highest part of the dome.

This is the line of dark craters running obliquely across the picture, set at an angle to the more northern line, if one may judge from 2 and 7, rather than offset, as the Bulletin has it. Plate XIX of the Bulletin, which is of nearly the same aspect as 7, describes the foreground crater as of white pumice underlying rhyolite, and the topmost dark layer as lapilli from the eruption.

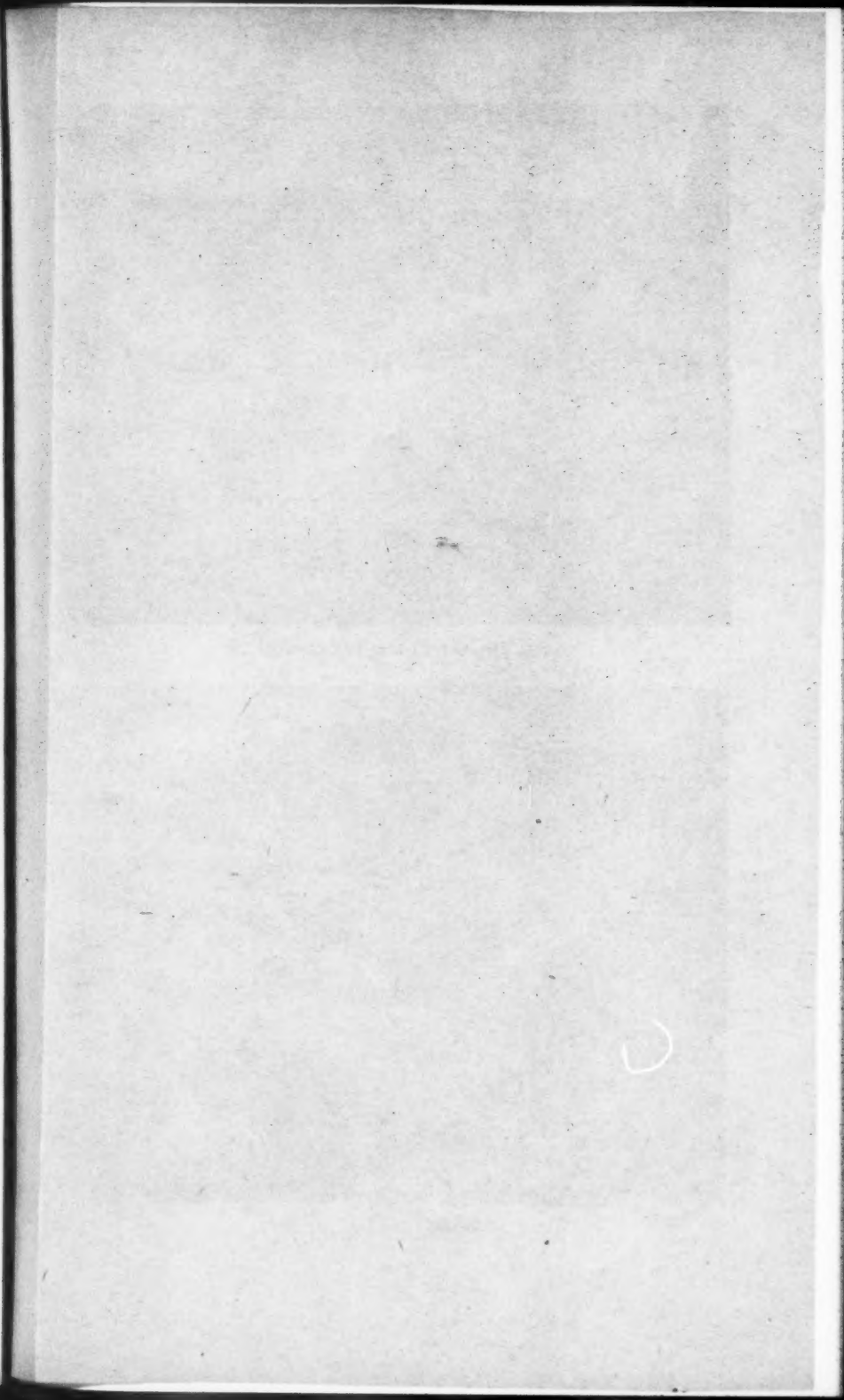
No. 3 is taken from nearly over the summit of Tarawera looking about south-west, a little to the south of the rift-axis, over lake Rotomahana. When the rift reached the lake, which was then much less extensive than the present, there was an immense explosion of steam and mud, the white and pink terraces were blown up or overwhelmed, and an immense crater was left, which is shown on Plan 3 of S. Percy Smith's report to the Surveyor-General dated 1886. Between it and Tarawera lay another crater Rotomakiriri, much

enlarged from the former of the same name. As the eruptions of mud and steam died down hot lakes formed in the craters, they gradually filled, and it would seem that the present lake Rotomahana fills the two basins, for the quarter-inch map dated 1928, which is included in Bulletin No. 37, shows Green Lake crater at the north-eastern end of Rotomahana at the foot of the Tarawera chasm, whereas it was shown by Smith in his Map 2 at the north-eastern end of Rotomakiriri. The mountain Maungakakaramea (Rainbow Mountain, 2494 feet) is that with two white patches above the island; the nearer of the two to the right is Maungaongaonga 2764, and the farther is Paeroa, 3264 feet. Echo Crater and its neighbours lie somewhere about the white patch beyond the lake shore on the right-hand edge of the picture. A very faint white summit just to the left of the centre at 1.9,2.9 in the extreme distance is Ruapehu, 9175 feet, some 90 miles away.

No. 4 is taken from a point a little south of No. 3, but looking about north-west, over the northern end of Rotomahana, across Tarawera lake, to lake Rotorua. The three are respectively 1095, 975, and 915 feet above sea-level, according to the quarter-inch map of 1928. We find no mention of lake gauges, nor whether Rotomahana is still rising. No outlet is shown on the map, nor is there any indication of the height of the ridge which separates it from lake Tarawera, 120 feet below it. The small lake 3.5,0.8 is near the position assigned to Green Lake crater, and this north-eastern end of the main lake is presumably the old lake Rotomakiriri. The water of the lake looks so white on the photograph because it is opaque, of a dull greenish grey. The two Maori villages, Te Ariki and Moura, which were destroyed in 1886, were on the tips of the two peninsulas in lake Tarawera, at 1.4,1.4 and 2.6,1.8. Lake Okareka is seen in part at 1.6,2.3, and Okataina at 3.9,2.2.

No. 8 looks about north-east by east across the complicated series of craters south-west of Rotomahana, in the line of the mile-long chasm through Tarawera seen foreshortened in the distance. On the sketch-map facing p. 93 of Bulletin No. 37 they are named Southern Crater at 2.4,0.9, Echo Crater and Frying-pan Flat at 1.8,1.6, Inferno at 1.8,2.1, Fairy Crater at 1.7,2.5, and Black Crater at 1.4,2.6 of our photograph. Southern Crater is described in the Bulletin as about 5 chains across, 100 feet deep, with hot pools, one cold pool, and weak steam-vents on its floor. Echo Crater was after 1886 a lake surrounded by steep cliffs except on the north, and later a flat with hot springs bubbling up under Gibraltar Rock at 1.7,1.8. On 1 April 1917 it blew up and the detail was much changed, so that it is not easy to reconcile pictures made before and after the explosion. From the name Frying-pan Flat used in the Bulletin, and the description of a lakelet and small hot pools, it must have been nearly dry in recent years, but No. 5 shows it full again at the end of 1937. On the Bulletin sketch-map it is shown as draining into Rotomahana, by what is called Haumi Str. on the map and Waimangu Creek in the text.

Somewhere between the far end of Frying-pan Flat or lake and the conspicuous Inferno Crater at 1.8,2.1 was the celebrated Waimangu Geyser which was first reported in January 1900, and until June or July 1904 threw up mud, sand, and immense boulders in huge columns of dirty black water to 1500 feet (J. Mackintosh Bell, *Geogr. J.* 27 (1906) 379). Bell says "nearly



5. Echo Crater and Frying-pan Lake

6. Inferno Crater

7. The rift through Ruawahia, looking south-west

8. Echo Lake, Rotomahana, and Tarawera

every day and sometimes more frequently"; the Bulletin says "with remarkable regularity every thirty-six hours." After remaining dormant for some fifty-five days it was active again until November 1904, when it ceased, and the vent was filled by the explosion of 1917. It is not easy to identify the site. Mackintosh Bell speaks of the "great deep craters of the Inferno and Waimangu" as just south-west of the Fourth Crater, which is presumably Fairy Crater at 1.7,2.5. The Bulletin speaks on p. 85 of "the pool to the south of Frying-pan Flat, the site of the old Waimangu Geyser," but on p. 93 of "Waimangu Geyser . . . on the flat a few chains east of Frying-pan Flat." But plate XXII shows the Crater of Waimangu Geyser looking uncommonly like Inferno, and it seems likely that a guide has sometimes of late pointed out Inferno as Waimangu. At 1.9,2.0 on No. 8, a little to the right and below Inferno, there is what looks like a small crater overgrown with bushes; this may be Waimangu, for it agrees very well in position with the Mackintosh Bell sketch-map on p. 375 *loc. cit.*

Fairy Crater at 1.7,2.5 has steep tall walls with a little steam coming from the sides; Black Crater has two deep funnel-shaped holes divided by a low partition which agrees well enough with the photograph.

No. 5 shows Frying-pan Flat or lake from its north-eastern end, and is not very easy to reconcile with No. 8, seen from the opposite point. The tall cliffs on the right must be Gibraltar Rock, but the island and the barriers which nearly cut the lake in two are not apparent in No. 8, which does however show a mottling of steam over the main area, that must be hiding detail at the far end. Probably the greater part of the lake is beyond the barrier, under the cloud of steam on No. 5, and the space in the foreground of 5 a small area at the far end of 8 imperfectly seen.

No. 6 is the Inferno Crater at close range. Bulletin No. 37 says that its deep greenish-coloured acid pool is at 70° C. For fifteen days it remains below the outflow level, sometimes as much as 40 feet below the lip; then it overflows strongly for four days, probably over the little white beach at 2.3,1.3, into the stream which runs along the bottom of the picture. The overgrown crater below and to the right is not so striking here, seen at close quarters, as it is on 8, but it can be traced, and seems the most probable site of the old Waimangu geyser.

Note by the Editor.—Some of the identifications in the above description of the photographs have been made while this paper was being prepared for the printer, and any errors should therefore be attributed to the editor rather than to the author, who has not been able to see the proofs.

An Appendix to Bulletin 37 contains proposals for establishing a vulcanological observatory, with particular stress upon predicting future eruptions in a region which contains much the best land at present undeveloped in New Zealand. Whatever may be the value or even the advisability of predictions, there can be no doubt of the value of systematic observation in the most active areas. The observations proposed are temperatures, analyses, discharges, seismograms, levels and tilts, gravity, and magnetism; to these one might wish to add, first and foremost a proper topographical survey, for at present there seems to be nothing better than the uncontoured quarter-inch

map of the district. Second, may one suggest a photographic record from fixed stations and on fixed bearings, carefully dated and repeated at regular intervals, with supplements on any activity of note; none of the excellent photographs in the Bulletin are dated. This survey might be made with a phototheodolite from measured bases and on control points, so that it might eventually if not immediately be plotted stereographically. Thirdly, one would like to see close profiles of the lake beds by echo-sounding, controlled by lake gauges tied to the lines of levelling. It is at any rate pleasant to imagine now these things included in plans for a better future.

All the alkaline geysers and hot springs deposit around them what in this connection is called *sinter*, which is 85–90 per cent. silica and the rest mostly water, with variable small quantities of alumina, lime, soda, and potash; and sometimes metallic salts of iron, manganese, and titanium. Sinter is chemically much the same as opal. A geyser will build a great mound of sinter round its vent, and the water flowing away after each eruption will make a crust of sinter on the surrounding ground. If the water flows down a slope of regular gradient the crust will tend to be in terraces. There are very many such elementary terraces of small size in the district, but none have the structural beauty of the lost white and pink terraces of Rotomahana, where each perfectly level step, from 1 to 6 or 8 feet high, was formed of a series of arcs enclosing basins. One may suppose that the hot mineralized water would deposit its silica most readily where it was suddenly cooled, so that if a basin were once formed, and from time to time was filled and overflowed, the rim which had been standing just above water and was cooled in the air would collect more silica on its rim and outer face than it would in the bowl, which would be warmer. Thus a basin once formed would tend to grow up and outward. The key to the origin of the basin may perhaps be found in Waikite; the Bulletin describes very briefly how in the overflow channel of this spring roundish cakes of sinter with raised edges have been formed (p. 118, and Plate XXXI.3 which has no scale and so gives no idea of the size of the cakes). One may suppose that essential requirements for a fine terrace would be a sound foundation of gently sloping rock, a regular and frequent discharge of water at just the right temperature to unload its silica rapidly upon an air-cooled rim, and water without any trace of mud. These requirements are exacting and may be rare in the right combination. When they exist together the process of terrace building seems to be rapid, for Froude observed that petals of flowers were enclosed before they had time to wither.

The Bulletin gives many detailed analyses of geyser and hot-spring waters and their dissolved gases, but says nothing of any tests for radio-activity or for helium.

A. R. H.

DISCUSSION

Before the paper the PRESIDENT (Field-Marshal Sir PHILIP CHETWODE) said: Mr. Alan Browne is well known to our Society as a climber and a watercolour painter of distinction. We have on more than one occasion shown his paintings in the Society's Exhibition Room, and a small selection can now be seen in one of the Museum cases.

From his very wide knowledge of New Zealand Mr. Browne is to give us

this afternoon an account, not so much of the high mountains and glaciers as of the volcanic and thermal regions in the north island. It is more than fifty years since the great explosion at Rotorua destroyed the pink and white terraces that were among the natural wonders of the world. We should be particularly interested to learn from Mr. Browne what is the possibility of those wonders being, in time, restored.

Mr. Browne then delivered his lecture.

The PRESIDENT: I fear it is too late for questions or debate on an exceedingly interesting lecture: so interesting and the photographs so wonderful that we have not noticed the passage of time. May I ask you now to show your appreciation by thanking Mr. Browne for one of the most beautiful series of photographs we have ever had an opportunity to see in this Society.

PORT FACILITIES AND THE DISPERSAL OF INDUSTRY: THE PROBLEM IN SCOTLAND

ANDREW C. O'DELL

Meeting of the Society, 10 February 1941

THE last few years have seen a growing tendency to regard dispersal of industry as the panacea for the obvious ills consequent upon industrial concentration, and many Town Planners appear to regard it as a simple matter to select new sites and clear the old and more congested without attention to geographically relevant factors such as port facilities. The purpose of this brief paper is to indicate how the ports, in and out of which the life-blood of our industrial organization must ultimately flow, have accelerated the tendency to concentration of industry and how the elaborate equipment needed for modern ports can not be lightly scrapped or created at the whim of the planner. Ports are controlled by the permanent and inescapable physical geography of the land and sea conditions. In the past there were one hundred and forty small harbours girdling the mainland of Scotland, such as Wigtown, Eyemouth, and Helmsdale, allowing the raw materials of local industries to pass in and the products to be passed out. To-day many of these are but decaying quays—whether because of sea conditions or because of the changing economy of the land.

The basic function of a port is to facilitate the transfer of freight and passengers between the water carriers and the hinterland.[1] Once established port facilities exist however this function is transcended. Factories crowd round the port in order to reduce transport charges, and the development of port and industries act and react one upon the other. The advantage of establishing industrial plant near a port was well set out in the publicity campaign for Trafford Park on the Manchester Ship Canal. It was shown that 9*s*.–17*s*. a ton haulage was saved over Liverpool, for proximity of factories to the Canal meant avoiding the tedious and expensive cartage charges at the older port.

The hinterland is divisible into three parts: [2]

The local hinterland which is almost non-competitive, within which the goods can be immediately conveyed by lorry.

The port's own back country which should be cheaply served by the port owing to proximity.

The competitive hinterland, where shippers have almost equal choice of several gateways.

Actually it is impossible from available data to draw rigid lines dividing an industrial region such as the Central Lowlands of Scotland into these three-fold port zones. Glasgow for example dominates the whole of the country for certain commodities, while the Lanarkshire coal pits, owing to the close network of railways, export coal through a variety of ports although they lie within the close hinterland of Glasgow.

Coal rates from Westburn Pit [3]

		Rate per ton	*Rate per ton-mile*
To Glasgow	7 m.	1s. 2½d.	2·07d.
Grangemouth ..	28	2 0	0·86
Leith	44	2 6	0·68
Granton	34	2 2½	0·78

Port charges also produce some anomalies in specific goods handled. Before 1908 £10,000 worth of iron ore was imported each year at Bo'ness, but in that year the dockers demanded 1*d.* a ton increase, and the ore imports were immediately transferred to Grangemouth. The values of paper material imported at this date for Leith and Granton respectively were £0·1 million and £0·3 million: the latter port is not more favourably situated in respect of the paper mills, but the dues are lower.

Many ports, for the sake of revenue, attempt to force too much traffic through the bottleneck of the transhipment quays, and this ultimately spells inefficiency. A marine terminal is essentially a national and not a local or private utility and should be organized in public interests. To meet this problem in Britain the port as a Public Trust has developed from its initial start at Liverpool where the non-profit-making concept has led to spectacular developments. The ownership of the principal ports of Scotland is given in Table I. The railway-owned ports are in the most advantageous position for attracting traffic, since they are best able, through their commercial agents, to press their claims. The two most effective points of appeal to the shipper are

Table I. Ownership of the principal Scottish ports and details of their capacity.[4]

	Owners.	*Water area.*	*Depth at H.W.*	*Quay length.*	*Repair docks: largest.*	
Aberdeen	Harbour Com.	85 acres	13–24½ ft.	19,229 ft.	3	310×66½ ft.
Burntisland	L.N.E.R.	17	8–22½	4,395	—	—
Dundee	Trust	35½	up to 28	18,209	2	516×49
Glasgow	Clyde Navign.	368	up to 32	62,915	—	880×83
Grangemouth	L.M.S.R.	57¾	17–26	15,098	3	350×50
Granton	Private co.	129	13–21	5,000	—	—
Greenock	Trust	42¼	14–32	19,600	2	640×69
Leith	Trust	75½	up to 30	24,970	8	550×70
Methil	L.N.E.R.	27½	up to 32	10,240	—	—

low dues and rapid dispatch facilities for "the point where rail and water meet, the port, is the point of greatest loss or saving in foreign, coastwise, or intercoastal shipping." [5] Dispatch facilities depend not only on port equipment but also obviously on the frequency of sailings in which the major port has so great an advantage.

The efficiency of a port is nevertheless not measured merely by its size but by the performance, and there are several methods of so judging:

Average number of days vessels in port, *i.e.* turn-round time.

Average amount of tonnage transferred in and out for each linear yard of improved waterfront.

Average tonnage per square foot of transit sheds.

Cargo tonnage per £ of operation costs and depreciation.

All these criteria have been adversely criticized but all are preferable to a study

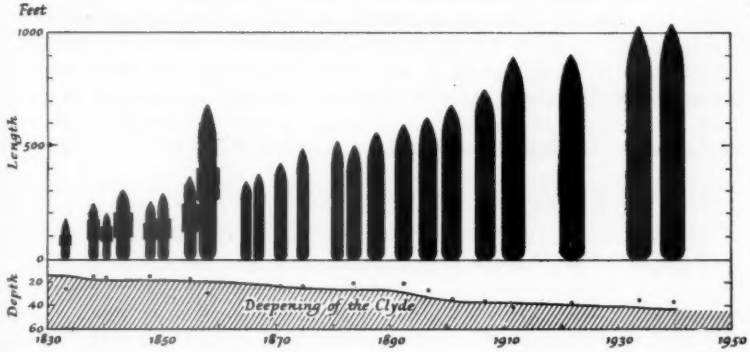


Fig. 1. Increase in ship size and progressive deepening of the Clyde, in part after A. C. Gardner

of the profit-and-loss account as a national criterion of port efficiency. It is intensity of use which counts.

So-called Free Ports, *e.g.* Hamburg, within which customs dues are remitted, are really possible only in protectionist countries. Entrepôt centres have been stimulated in Britain by the bonded warehouse system. In these warehouses storage, sorting, mixing, but not manufacturing, of dutiable goods is permitted. In a Free Port industries such as shipbuilding which demand cheap raw materials can develop owing to the saving of duty, as they have the right to manufacture.

The equipment of a port must progressively improve to maintain the trade handled: the layout as well as the appliances being understood in the term equipment. The size of ships has increased in a spectacular manner through the last hundred years, as shown in Fig. 1. In 1845 the West Indies trade to Glasgow was handled in vessels of 180–500 tons, no larger in burden than those of Elizabethan days but of considerably larger dimensions. Even in 1864 there was no steamship above 1000 tons, in 1879 only one above 4000

tons, and in 1899 the first 7000 tons gross vessel was built. At the present time there is a tendency to build cargo vessels of 5000–8000 tons as the most favoured size, and there are so many vessels of 27–29 feet draught as to make a port second rate if it cannot accommodate them. In 1875 a 3000-ton ship had space for 2200 tons of bunker coal and 800 tons of cargo, but by 1899 the proportions had been reversed, due to the development of the triple and quadruple expansion engines in 1882–84.[6] These larger capacity ships mean that there must be more facilities for cargo handling along each unit length of quay. The century's progressive increase of size for the major liners of the world is seen in Table II. These great vessels need a quick turn-round to reduce the tremendous daily overhead costs, and this has meant that ports which cater for them have had to provide improved appliances for cargo handling, bunkering, and watering, as well as an adequate dock labour pool. These points are of accentuated importance when shipping tonnage is scarce. These increases have also demanded progressive improvements in depth and other clearances, and ports unable to stay the pace have languished from self-strangulation, while even such trade as might have continued in smaller vessels has too often passed to the better provided ports. Once regular shipping lines use a port there is a natural tendency for freight to be sent there for shipment, as the chances of lifting are greater. The relative capacity of the major Scottish ports has been summarized in Table I.

Table II: Number of vessels over 10,000 *tons.*[7]

Year.	10–20	20–30	30–40	40–50	*Over* 50	*Total over* 10,000 *tons.*
1891–92 ..	2	—	—	—	—	2
1894–95 ..	4	—	—	—	—	4
1899–1900	33	—	—	—	—	33
1904–05 ..	85	6	—	—	—	91
1909–10 ..	122	9	2	—	—	133
1914–15 ..	212	11	4	2	2	232
1919–20 ..	209	14	3	3	3	231
1925–26 ..	214	27	4	3	3	350
1938–39 ..	465	60	7	5	5	542

The equipment of major ports demands repair facilities, which include graving docks, patent or marine railways and floating docks. These, particularly the expensive graving dock, are usually unremunerative in themselves but justify their creation by attracting regular shipping lines. The associated supply of skilled engineers, pilots, and workmen must not be overlooked.

Some commodities need special appliances for ease of handling. In Scotland the most important of these is coal, for which various methods are: [8]

Staiths—best developed in Northumberland, where the topography is most suitable: none in Scotland.

Hoists—usually hydraulic save at Glasgow, where the first electric hoists in Britain were installed. These hoists can lift 20-ton end-door wagons.

Belt conveyors—costing approximately the same to work as electric hoists.

Crane—at Glasgow and other ports considerable quantities of coal so

shipped by lifting wagon or container by crane over the vessel's side and so limiting breakage.

Aerial ropeway—none in Scotland.

Discharge was originally by whipping baskets up by a pulley, but nowadays it is done by grab buckets and gantry cranes at the better equipped ports.

Oil is moved by buried pipelines, usually from isolated docks or wharves to the storage centre.[9] Grain is dealt with by pneumatic plant which can convey it from the ship to a relatively distant granary. Timber is a seasonal trade and the sawn planks (the form in which it usually arrives now) are conveyed by transporters or by crane and sling. Ore is moved by crane. General cargo is shifted by travelling cranes with a normal maximum lift of 2 tons. Heavy lifts can be dealt with by floating cranes or by sheer legs.

Railway access is obviously essential for a modern port, and the main desiderata are:

Loading sidings at the wharves, warehouses, etc.

Storage yards for the wagons.

Sorting yards.

An outer line tapping all freight lines before they enter the congested part of the city.

An inner line to allow all piers to be served one from another.

Some Scottish ports have many miles of railway under their control, *e.g.* Leith 27 miles, and although these mileages do not reach Hamburg's 185 miles they are, in most cases, adequate for their task. This rail linking has been especially well developed with such ports as Methil and Grangemouth, for they are railway owned and the ports have spared no effort to stimulate trade. Burntisland possessed an excellent natural harbour but no productive local hinterland. The N.B.R., now the L.N.E.R., developed the port at a cost of £150,000, and the harbour revenue rose from £197 in 1850 to £14,785 in 1885 although there were but circuitous mineral lines to the collieries.[10] In 1912–13 Methil, lacking a natural harbour but with shorter routes to the coalfield, outdistanced Burntisland.

At some ports lighters must be used to lighten ships and reduce their draught. Before the deepening of the Clyde, vessels were lightened at Greenock and a towing-path was provided along those stretches of the river unsuitable for sailing. Lighters have the undesirable aspect of offering chances for pilfering cargoes. Cartage causes congestion on the road approaches as well as on the quays, and so should be kept to a minimum. Railway depots are the best means of reducing road haulage from the quays to outlying factories.

The classification of ports has often been attempted and the following simple scheme is suggested:

Natural harbours

Those with a wide tidal range, over 12 feet, necessitating massive dock construction with masonry walls. The first wet dock was built at Plymouth 1697 and the first commercial one at Liverpool in 1715. This latter was built because of the great tidal range, 27½ feet.

Those with smaller tidal range when wharves are either timber or freestone as at Lerwick, Scrabster, etc.

Artificial harbours

Narrow rivers needing excavated basins with either tidal or wet docks according to the tidal range, *e.g.* Aberdeen docks.

Open bays protected by breakwaters, as Peterhead Harbour of Refuge.

Rivers with training walls to maintain depth, but with wharves along the river banks.

Pier built at right-angles to the shore to provide lee on one side or other, as in the original pier at Granton, which had a central parapet.

The long history of most Scottish ports has meant that most have developed on the lines of more than one of the above types, *e.g.* Dundee had both wet docks and wharves built according to the requirements and engineering ability of the time. Docks have the advantage of not straining the bottoms of the vessels and cargo handling can go on constantly without great lifts.

The distance of British harbours from the open sea is often considerable. The deep penetration of the Scottish estuaries has been of fundamental importance in the development of the ports: the site of many determined by deep water close inshore as at Dundee on the Tay, Rosyth on the Forth, and Greenock on the Clyde. In other cases, as at Grangemouth and Glasgow, the ports have only been situated on the estuaries by prodigious engineering efforts. The greatest trouble with most ports has been to provide sufficient depth of water for the ever-increasing size of vessels and since, at the time of steamship development, the capacity varied as the cube of the draught, depth was, and still is, of vital importance to shipowners. In disturbed water 3 feet is needed under the keel for the vertical *scend* of the ship.

The necessary depths of water as shown in Table I have been obtained by:

Dredging and training of the channel, *e.g.* the Clyde.

Dredging and training of the tidal and river flow over the bar, *e.g.* in the Dee at Aberdeen.

Building breakwaters out into deep water, *e.g.* Peterhead Harbour of Refuge.

Reclamation of the foreshore for wet docks, *e.g.* Grangemouth.

By making Albert Dock, Leith, 2 feet deeper than Victoria Dock a depth of 23 feet was secured for two hundred and ninety-six tides in a year as against only one hundred and two for the latter. The training of a river has to be done with care. The Clyde was considerably narrower in early days and when the need for a wider channel came, the reclaimed land had to be obtained from the riparian landowners at considerable cost. It was found, too, that narrowing the upper estuary between Dundee and Perth so reduced the tidal prism, or volume of water, entering the Firth that silting up of the lower estuary was encouraged and consequently the river had to be allowed to revert to its former channel.

Protection from wave action is most difficult to provide when the waves come directly onshore—the quay of Victoria Harbour, Dundee, needed massive building as it lay nearly dead on to the main fetch of the waves.

Here the force of the storm waves was measured as 3^{1}_{2} tons per square foot, presenting a considerable problem in the layout of an exposed port. At Portpatrick works costing £0·5 million had to be abandoned by the cross-channel steamers within twenty years owing to gale damage.

Again the situation of tidal currents can be important in the location of a port. The strong currents running on the north side of the Tay have been of fundamental importance in keeping the approach to Dundee relatively free from silting up. Montrose's approach channel has a current of 6 knots, owing to the great volume of tide entering the basin, and this is sufficient to give a dangerous sea where it meets open water. Such harbours as Lerwick, Aberdeen, and Glasgow are exposed to but weak tidal currents.

Fog can be a serious problem for navigation, particularly in the most crowded estuaries—the Clyde and the Forth. Industrial pollution is an important factor in determining the amount of fog, and Clydeside is the worst area.[11] Fog spreads with the prevailing westerlies from here as far north as Aberdeen. On the east coast the Firth of Forth is the foggiest sea area (443 hours a year, 1925–34 average) and the Moray Firth the least (112 hours). This latter may be due to the westerlies being stripped of their moisture by the mountains before reaching the sea. The west coast has less fog than the east, and most fog occurs in July while the east coast has its maximum in May, except for the Firth of Forth area. This has its maximum in winter, as it is strongly affected by land fog and so resembles the Clyde. Many lighthouses have been built too high, and are shrouded in cloud and fog when the sea surface is clear, *e.g.* Barra Head (629 feet) reports 1017 hours of fog a year and Monach (28 feet) equally exposed reports 177 hours.

Ice is not a serious obstacle to British ports, although when it was proposed to have a wet dock at Aberdeen it was objected to as likely to cause delays due to freezing, and it was then stated that ice had closed the port for eight days in the winter 1809–10.

The geological control of port sites is yet another factor that may be crucial. Outcrops of useful rocks may necessitate a harbour, as Limekilns Harbour on the northern shore of the Firth of Forth near the Earl of Elgin's limestone workings, but geology may also determine the actual site. At St. Monance Harbour the Harbour Coal seam, folded and eroded, forms the harbour fairway. Port Seton Harbour is situated in a natural hollow eroded in a small basin of the Coal Measures while harbour wings are provided by the massive Millstone Grit. While these are insignificant examples they have been selected as being uncomplicated. Had it not been for the Clyde flowing in a valley carved in glacial deposits it would have been impossible to dredge the channel which now takes a modern liner. The narrow sill of whinstone, across the Clyde at Elderslie, which cost £210,000 to blast away to give 28 feet at low water, illustrates the control that geology may exert over economic port construction.

Relief exercises a slighter control of port sites than might be thought, although it affects the layout of towns and communications. Two well-marked contrasting sites are those of Grangemouth and Greenock. The former established in 1770 at the Sea Lock (its original name) of the Forth and Clyde Canal has, since the railway purchased it in 1867, developed

rapidly and easily on the slob lands of the Forth estuary. These provided ample room for the layout of railway yards, oil, timber, and other special storage depots. Greenock on the other hand is situated in a re-entrant into high land. At first the town lay on the shore, but congestion became acute as harbour, shipyards, and sugar refineries commandeered the best sites. Later factories and dwellings had to be placed in side valleys. The railway sorting yards have had, of necessity, to be placed away from the harbour on account of the lack of flat land. At many ports, for example Burntisland, buildings have found convenient sites on the flat-topped 25-foot raised beach.

Minor river obstructions are usually regarded as leading to silting, and while they undoubtedly lead to changes in the sand banks when massive (the Tay Bridge piers are nearly one-eighth mile wide in the aggregate), modern research work has given the revolutionary suggestion that they are, if anything, beneficial, as scour is increased.[12] Bridges are an obstruction to vessels, because of the restriction of head room, and some, as the new Kincardine Road Bridge, have had to provide the expensive and time-consuming moving span.

The development of a port is naturally dependent on the industrialization of the hinterland. There are many inlets with magnificent anchorages in the Highlands which remain unused, save for such rare exceptions as Lerwick and Ballachulish. Packed into the Central Lowlands is the mass of the population, associated with the greatest degree of industrialization, and it is significant that here are found all the great ports save those which specialize in fishing. As Fig. 2 shows, the area has intimate relationship with the ports and no part is more than 16 miles from an important port. At first examination it would appear that all districts of the Central Lowlands were almost equally situated from port facilities. Nevertheless the high proportion which transport charges form in the selling costs of goods demands that these be minutely scrutinized. Hence industry is not spaced equally over the whole region but clings closely to the ports. Coal is an important export commodity and, as can be seen from Fig. 3, where the collieries are at the greatest distance from the sea, all coal workings are within easy distance of ports equipped for coal shipment. The coalfields are served by an intricate network of railways, and indeed it was here railways were first developed in Scotland, at first to feed the canals, but subsequently as their rivals.

Certain industries require bulky imports of raw materials, and in the immediate vicinity of the waterfront are found various consuming factories. To divorce the factories from this proximity would be to place a severe handicap on the industries in meeting the competition of foreign producers. With some industries, as pig iron manufacture, where coal forms a bulky item of the fabrication, it is convenient to have the manufacture on the coalfield and the railways to carry the raw material, in this case iron ore, from the port. South-east of Glasgow lie the great iron and steel works of Scotland, and in 1930 a proposal was considered to erect furnaces at Elderslie, bringing the iron ore from abroad to a new dock and coal from Kilsyth and Monklands. Such a proposal was only feasible by recent technical improvements which had reduced the coal consumption to 1·75 tons per ton of pig iron produced. Pre-

vious to this reduction coal transport charges would have been so high that no ironmaster could have considered the proposition.

Textiles form an important example of the normal relationship as is seen in the concentration of the more important manufacturers of flax, jute, and hemp in the vicinity of Dundee, Kirkcaldy, Arbroath, and Montrose, and cotton only 5 miles west of Glasgow. Wool forms an exception to this generalization for Australian wool is sent to the Border woollen towns: an exception to be

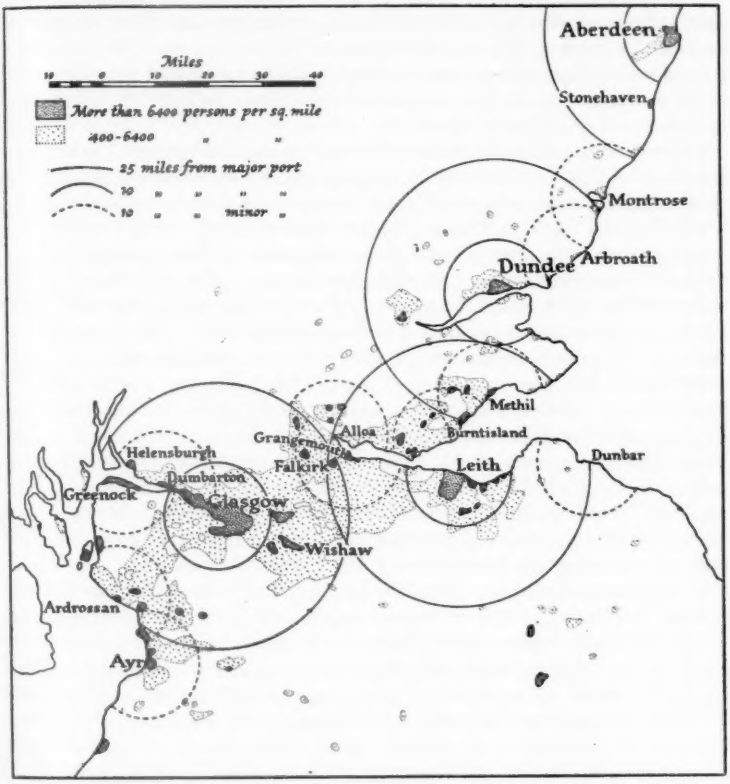


Fig. 2. Relation of ports to industrial areas of Central Lowlands

explained by the high quality and specialized character of the finished product which can stand higher transport charges and defy competition. Flour-milling centres have left the old river sites for ports at the point of grain import. This tendency first became marked in the 1860's with the rise of the New World as a grain supplier. Paper is another commodity depending upon bulk materials (china clay, pulp, and esparto grass) and the industry is most economically sited on rivers with suitable water near to major ports.

Oil, because of its dangerous character, is usually dealt with away from the

main ports. Bowling is an important oil centre and is connected to the Forth estuary by a pipeline which was opened November 1918 for war requirements. Livestock, timber, and fish all demand special facilities which have been provided at Glasgow, Grangemouth, and Aberdeen respectively. Livestock, of course, seek the big consuming centres, timber and fish need large spaces for storing and curing, and find these more cheaply at the lesser ports.

As ports essentially serve the national rather than private interests the Government passed a Bill in 1861 by which loans under £100,000 at $3\frac{1}{4}$ per cent. interest were to be made available for port authorities. They also had an examination made of the question of shelter for vessels, a more serious one in the old sailing days, and as a result of the findings of a Royal Commission the construction of the, as yet, unfinished Peterhead Harbour of Refuge was undertaken, using convict labour.

Fig. 3 showed some of the principal features of the Clyde ports. The narrowing of the channel is indicated by the stippling for the mud and sand banks exposed at low water. Greenock arose owing to the deep-water anchorage at the Tail o' the Bank, and when Glasgow Burgh in 1668 wished to obtain a port under its control the adjoining site of Newark, the nearest deep water to Glasgow, was purchased and Port Glasgow commenced. This port, despite elaborate harbour works, fell from its high estate with the canalization of the Clyde permitting large vessels to ascend to Glasgow itself. This illustrates the desire to take vessels as near the industrial centre as possible, and is an argument against the dispersal of port sites. The figure also shows how the lower valley of the Clyde forms a well-marked region with the industrial boundary and 500-foot contour approximately coinciding. The breaks in the higher land to the west, north, east, and south-east are all followed by important lines of communication. On this figure have been inserted the whole of the railway lines, whether passenger or mineral, and collieries shown on the 1-inch map; and while neither of these is complete they are sufficient to give a picture of the development. *Fig. 3 cannot be published.*

This compact industrial region, the principal in Scotland, owes its concentration of industry partly to natural causes and partly to historical. The essential step of deepening the channel could not have come about save for the existence of the glacial drift-filled valley marked in the diagram. The region is marked for its variety of products, although one district may only have one major industry, and also by the tenacity with which once an industry is adopted it has maintained a foothold in the region, altering if need be to suit changing conditions. A further point is the lateness with which it grew, for it was only in the nineteenth century that the resources could be exploited.

Besides the heavy industries, as shipbuilding, which arose owing to the juxtaposition of iron and coal deposits and a sheltered waterway, Glasgow has others which show the importance of an adjacent waterway. Sugar-refining machinery was established as a result of the West Indian trade and the commencement of sugar refining at Greenock in 1765. Calico printing was commenced in 1738, and for this the pure water from the hills was necessary. Thread manufacture began at Paisley early in the eighteenth century and with associated muslin and shirtings has gradually concentrated on the finer products to meet foreign competition. These manufactures all demanded an

easy import of foreign raw materials, and as a direct result of their presence the chemical industry was established in Glasgow to provide dyes in the first place. The Singer Sewing Machine Factory at Clydebank exports 80–90 per cent. of its products and still draws specialized parts from North America, and so it had to be established near a port with regular sailings both world-wide and to New York, which is near the parent factory. Glasgow has the shortest sailing distance of a major British port to New York, 2997 nautical miles.

Sufficient has been given of the Clyde area to show how the industries are interlocked with the port facilities, and it must be noted how the port has been divided to meet the problem of unwieldy size. For the year ending 30 June 1938 Glasgow imported 4 million tons of goods and exported 3 million. This gives 347 tons per yard of quay as against 576 tons in 1908 and 375 in 1872. Kingston Dock, opened in 1867, was for a time reserved for the Pacific trade, but after rebuilding in 1917 for general cargoes. Queen's Dock, opened 1880, provides for vessels trading to India and Africa. Prince's Dock, opened 1897, has traders to North and South America and has ore-discharging equipment. Meadowside Quay has Australian vessels and is equipped with a modern granary; while at Merkland Quay are lairage and fruit equipment. Shieldhall Wharf formerly provided for timber, but here was opened in 1931 King George V. Dock, the first instalment of what should be considered a new port. The quays were built of monolithic concrete as the massive modern port equipment demands more substantial quays than open stage work.[13]

Intermingled with the quays are the shipbuilding yards, while at Bowling emerges the Forth and Clyde Canal which is still of use for carrying coal, chemicals, timber, and other bulky commodities and has along its banks many industrial works. Since 1809 the river, from Albert Bridge to Port Glasgow and Cardross, has been under the control of the forty-two Commissioners of the Clyde Navigation Trust, who are representative of the cities, trade, and shipping of the region. The railway reticule has been provided by the railway companies, and not by the Trust, but it will be seen that these railway lines are adequate, running both parallel and radial to the Clyde, with sorting yards at positions suitable to meet the requirements outlined above. This is not to hold up Glasgow as an ideally planned port but to show how successive generations of engineers have built up a structure which, with its linear development, gets the advantages, and avoids most of the disadvantages, of the large port, dealing in a variety of heavy commodities to and from all the seven seas.

Future port development must be controlled with an eye to the needs of future generations. Too often in the past the work of one generation has had to be destroyed, instead of being developed, to meet the needs of the next. Offensive industries as oil, garbage disposal, gas and chemical works ought to be placed well to the leeward of the town. The plans for the growth of the port should envisage the need for road as well as rail transport, for a harbour for pleasure craft, for accessible dormitories for workers, and for a well-planned approach from the sea to the passenger quays. These gateways of the oceans deserve to be monumental and impressive: too often they are merely squalid.

The elaborate equipment necessary to a modern port means that the con-

struction of new anchorages is not to be lightly undertaken: the older ports as part and parcel of the world's shipping lanes have a grip of the trade of a district that is not to be readily lost. It must further be remembered that these ports have outdistanced the host of rivals, from which they were barely distinguishable in the seventeenth century, because they possessed natural advantages from the point of view of land or sea access. They were not created by decree. The mere spending of vast sums of money does not secure either efficiency or success. Over £11,000,000 were spent between 1809 and 1927 on the deepening and equipping of the Clyde with triumphant success; £1,000,000 was spent on the construction of the Caledonian Canal which remains as a monumental failure. In the one case the money was spent with regard, in the other case with disregard, to the practical potentialities of the region and the value of the waterway as an artery of commerce.

With improvement in the transport and other agencies in the last hundred years towns grew, and it was only with this century there arose the concept that the bigger might not be the better. Provided a port can efficiently discharge its function there is no limit to the size, but once the optimum of efficiency is passed, then every increase of size leads to further delays, principally concerned with the land transport. If the problem of distribution of industrial works is controlled, cognate industries will have to be adjoining, and who can separate coal, iron, steel, marine engineering, and shipbuilding from port facilities or from one another in the area most closely examined in this paper?

REFERENCES

1. MacElwee, R. S., Port development, 1926, p. 3.
2. *Ibid.*, p. 5.
3. Royal Commission on Coal Supplies, 1905. Evidence of D. M. Stevenson.
4. French, W., Scottish Ports, 1938.
5. MacElwee, p. 65.
6. Chisholm, G., *Scot. G. Mag.*, 1909, pp. 561–76.
7. Kirkpatrick, C. R. S., Inst.C.E., Vernon-Harcourt Lecture, 1925–26.
8. Gedye, N. G., *ibid.*, 1931–32.
9. Reed, H. A., *ibid.*, 1927–28.
10. Saunders, L. J., *Scot. G. Mag.*, 29 (1913), pp. 67–87 and 133–48.
11. Dixon, F. E., Met. Off., Prof. Notes, No. 88, 1939.
12. Gibson, A. H., *Proc. Inst. C.E.* (1938), pp. 210 *et seq.*
13. Gardner, A. C., *Proc. Inst. C.E.*, 1940, pp. 29–52, Vernon-Harcourt Lecture, 1939–40.

In addition to the above the B.A. Handbook to the Glasgow Meeting, 1928, and the Board of Trade Industrial Survey of the South-West of Scotland, 1932, have provided information.

DISCUSSION

Before the paper the CHAIRMAN (Admiral Sir WILLIAM GOODENOUGH) said: Professor Debenham is unfortunately unable owing to illness to read this afternoon the paper on "A laboratory for physical geography" announced in our programme. We are immensely indebted to Mr. Andrew O'Dell, who has been able at short notice to give us instead his paper on "Port facilities and the dis-

persal of industry: the problem in Scotland," which should make a useful contribution to that discussion of planning for the future which is necessarily exercising the minds of many, even though our immediate interests must be so largely in the present rather than the future. I may have something to say on the subject after we have heard what Mr. O'Dell has to tell us.

Mr. O'Dell then read the paper printed above.

The CHAIRMAN: The lecturer has placed himself and you in danger in that he has dealt with a subject on which, if I chose, I could speak for far longer than he has. Are there any questions?

Mr. G. R. CRONE: How long do steamers take to get up the Clyde to the centre of Glasgow?

Mr. O'DELL: Usually one tide from Greenock.

Colonel F. H. SMITH: I presume that the depths of from 20 to 40 feet given for the Clyde are high-water depths.

The CHAIRMAN: High water by the chart.

Colonel F. H. SMITH: Having had to wait three weeks to get a vessel launched, I speak sympathetically.

The CHAIRMAN: The lecturer ought to have had an audience of many hundreds, for his subject is one on which the future prosperity of this country depends. The very small ports are, of course, of importance to many, but what I hope the lecturer will turn his real constructive attention to are the large ports not only of Scotland but of England, and will bear in mind the human factor; it is curious that while the shipping industry is the most important in this country those who are occupied with and employed in that industry are the most neglected.

Ships draw much more water now than they did in the past, but there is a limit, set by the depth of water in the big harbours into which ships go abroad. When a tunnel under the Thames was planned it was insisted that it should be at a great depth because of the water ships might draw in the future: I think 45 feet was mentioned, but that was ridiculous, because ships drawing that could not get into most harbours abroad.

My business now is, on behalf of the Society, to thank Mr. O'Dell for what has been a most interesting lecture on a fascinating subject. We shall all be able to enjoy it again in the Society's *Journal*.

THE SPELLING OF TIBETAN PLACE NAMES

LIEUT.-COL. F. M. BAILEY, C.I.E.

TIBETAN spelling is extremely complicated. There are many silent letters; consonants are sometimes used solely to modify the sound of vowels, losing their own sound completely, and many letters in combination with others entirely change their own sound.

To take a few examples: Lama is spelt Blama, the *B* being silent. Chang-Ku, a wolf, is spelt Spyang-Ku, the *S* being silent and the *Py* being pronounced *Ch*. The word for Tibet is Pö, spelt Pod, the *d* completely losing its own sound but modifying the *o*. In outlying parts of Tibet, both east and west, silent letters are often pronounced, *e.g.* in Eastern Tibet the word for "wolf" is pronounced Spyangku and not Chang-Ku as in Lhasa.

If we attempt too meticulous a system we get ridiculous things like this: The Tibetan word for Sikkim is pronounced Dren-Dzong and spelt Abras-Ldzongs. The first *A* is silent but slightly alters the sound of the next letter. The *br* is pronounced *dr*; the *s* modifies the *a*; an *n* is inserted for euphony so we get Dren. In the next syllable the *L* at the beginning and the *s* at the end are silent.

In addition to the above there are several slightly different forms of the letters *k*, *ch*, *t*, *p*, and *ts*. If it is considered necessary to differentiate between these, diacritical marks must be used which, besides adding to the difficulties, are apt to be dropped in course of time with a result more misleading and inaccurate than a simpler approach to the subject would be. These diacritical marks may be necessary in a dictionary which would be used only by experts, but a thing like ξ on a map would be undesirable and in ordinary printing impossible. We should, I think, get the nearest we can to the correct sound with the use of the ordinary English alphabet, giving the English value to the consonants and the Italian value to the vowels. The more accurate pronunciation can be learnt by the traveller on the spot, or by the expert, who in any case would have to learn the meanings of the various marks in a more involved system. With the aid of the complicated system employed in the dictionaries it is possible to transliterate from the English back into the correct Tibetan spelling, but who wants to do this? Perhaps the very few experts.

The above will show the advisability of having a simple, practical system for maps and ordinary purposes used by ordinary people. Fortunately such a system already exists. In 1903 preparations were being made for the Younghusband Mission to Tibet and, in connection with these, Captain (now Sir Frederick) O'Connor, one of the only three officers of the army who had passed the examination in Tibetan, and the only one who had a fluent, colloquial knowledge, was asked to formulate a system. This he did and this system was accepted by the Government of India (including the Survey of India) and is the only recognized system for the transliteration of Tibetan names into English. Sir Frederick O'Connor's system of 1903 has recently been reprinted, and is no doubt available to those interested. There is a copy in the Society's Library.

In 1905 Mr. C. A. (now Sir Charles) Bell brought out his Manual of

Colloquial Tibetan. In this he, generally speaking, adopted O'Connor's system, but made a few alterations. I quote the following from his preface:

"A word as to the system of romanization. In this, which is believed to be as phonetic as possible, I had reluctantly to differ from the various systems of my predecessors, as none of them seemed to me to reproduce the sounds in the dialect of Lhasa, though some reproduced those in the Sikkimese and other dialects. The system followed in this book is nearly the same as that recommended to Government for official reports, etc., by Captain O'Connor, C.I.E., Trade Agent at Gyantse, and the author, but distinguishes the different sounds with greater accuracy than was necessary in the Government system."

The chief difference in this system was a compromise between the exaggerated system of diacritical marks of the dictionaries and the very simple and efficient official system. For instance, to take the different forms of *p*; the official system makes no difference, though it is noted that there is a difference of tone. Bell has *p*, *ph*, and *p'* (the latter being *b* in the official system, with a note to say it is sometimes pronounced *p*). Bell treated *k*, *ch*, *t*, and *ts* in the same way.

These three *p*'s did not, I think, improve things as far as geography was concerned, and Sir Charles Bell in his above-quoted preface suggests that his greater accuracy of distinction of sound was not considered necessary in the Government system. Therefore I suggest that we all adhere to the official system which has worked well for nearly forty years and which has never officially been displaced. Were all travellers to use the official system we should get a desirable uniformity in spelling which would avoid confusion.

Spelling of place-names in Tibet is still in a fluid state and a name may be spelt in different ways by different people, but I suggest that it be a rule that where one explorer has taken the trouble to get a name spelt in Tibetan and transliterated according to the recognized system, that name should, as a general rule, be allowed to stand. This will avoid confusion caused by constant changes. I know there may be exceptional cases: for instance, the earlier travellers may get a name spelt by a villager and a subsequent visitor may get it definitely corrected by some official who is accustomed to use another spelling in his records; in such a case the second spelling may be considered more correct and a change may be necessary; where this is done an explanation should be given.

I can see no reason against changing names that have not been spelt in Tibetan. In fact it is necessary in many cases to do so. The secret explorers of Tibet sent out by the Survey of India during last century usually spelt and pronounced the Tibetan *ts* as *ch*, *e.g.* Chetang for Tsetang (50 miles south-east of Lhasa).

Other complications arise which require special treatment. Letters are inserted or altered in speaking for the sake of euphony. It is difficult to formulate a rule for this. Then things are done that could only be done in Tibet! In 1913 Captain Morshead and I came to a village La-Yö-Ting. We had heard of this, but when getting it spelt the man would only write Da-Tring, emphasizing that it was quite impossible to write La-Yö-Ting, as that was only the pronunciation.

Another complication arises from the fact that the local pronunciation of a name may differ from the Lhasa pronunciation, but I have found that in most cases the Lhasa officials pronounce the names in their own way, just as in London we do not pronounce Edinburgh and Glasgow with a Scottish accent.

I give as an instance of unnecessary changes the Se La, a pass between Senge Dzong and Tawang. This pass was crossed and put on the map by Colonel Morshead and myself in 1913. The name was spelt for us as Se La (སེ་ལ།) by the monks of Tawang, who administered the district, and was transliterated according to the recognized rules. In his paper in the *Journal* for July 1940 Captain Kingdon Ward has altered this to Ze La. This is, I think, an instance of a quite unnecessary change. In neither the official system nor in Sir Charles Bell's would this be Ze La.

Note on Sir Frederick O'Connor's 'Rules for the phonetic transcription into English of Tibetan words.'

A small number of copies were printed by the Government of India Central Printing Office and issued as Paper No. 7 F.D., 12.4.1904. This paper has recently been reprinted with a slight correction but with the original date and no indication that it is not the original issue. These rules have never been on sale to the public and travellers have perhaps not always known how to obtain them from the Foreign Department or the Survey of India. It will be useful therefore to call attention to them, and to extract from them a brief statement of the alphabet's principal characteristics, to serve as a supplement to Colonel Bailey's paper.

Tibetan is written from left to right like Sanskrit and its derivative languages. The alphabet has thirty consonants, of which two are really initial vowels, or terminals to carry another vowel, or following a second consonant to suppress the sound of the first. Each consonant carries with it the inherent sound of *a*; that is to say, if no other vowel is written, a single consonant is read as if followed by the Italian *a*, or a pair of consonants is read as if the first is followed by a short *a* or indeterminate vowel.

There are four other vowels: *i*, *u*, *e*, and *o*, coming in this order in the alphabet. *I*, *e*, and *o* are represented by signs written over the consonant with the effect of substituting one or other of these vowels for the inherent *a*. *U* is represented by a sign written under the consonant with similar effect.

Seven of the consonants may be written with a *y* subjoined, fourteen with an *r*, one with an *h*, and six with an *l* subjoined; twelve may be written with an *r*, ten with an *l*, and eleven with an *s* superscribed; all these making double characters. There are also treble characters, combinations of the above; and characters written reversed right and left, which reversal sometimes affects the pronunciation, sometimes does not.

The pronunciation is governed by rules which silence certain initial or final consonants in a group of three and change their pronunciation when they are initial or final by themselves; and there are remarkable special rules for the consonant *b*. Five letters when first in a syllable of three or more characters are called prefixes and are silent, and ten letters, the former five and five more, are called affixes when last letters of a syllable of the word: one of each five is silent, the others pronounced but inaudible.—Ed. *G.J.*

REVIEWS

EUROPE

THE IBERIANS OF SPAIN AND THEIR RELATIONS WITH THE Aegean World. By PIERSON DIXON. *Oxford University Press*, 1940. 7½×5 *inches;* 170 *pages; plates.* 8*s* 6*d*

A larger work which Mr. Pierson Dixon had planned was thwarted by the Civil War; but the little book which has taken its place, handy in size and complete with appendices, plates, and sketch-maps, will perhaps be more welcome to the traveller. It should help him to understand some of the contrast he will feel as he descends from the central plateau to the Mediterranean fringe; or, taking a particular case, the association of Elche, famed to-day for its palmgroves and for being in appearance one of the most African villages in Spain, with the outstanding achievement of Ibero-Greek sculpture. At the beginning of the historical chapters which trace the influence of the Eastern Mediterranean on eastern Spain, the author distinguishes the two main characteristics of Iberian work: "a love of the decorative which often amounts to flamboyance, and a tendency to imitation which made the Iberian artist readily sensitive to the influences of an alien and a more vigorous culture." This theme is elaborated in the latter half of the book, which discusses vase-painting, sculpture, and ornaments; it is modified by the author's insistence on the readiness with which Iberian work can be recognized: the Iberian artist never lost his individuality. In the author's view, it was not until the Roman Conquest that Iberian art disappeared, and with it the distinction between Iberian and Celt. J. P. H. M.

CENTRAL AND SOUTH AMERICA

LA SELVA PERUANA. By Dr. C. A. PAZ SOLDAN and Dr. M. KUCZYNSKI-GODARD. *Lima: Instituto de Medicina Social*, 1939. 10×14 *inches;* v+68 *pages;* 100 *plates*

Peru possesses an enormous area of rain forest on the eastern flanks of the Cordillera which presents a problem to a government requiring to make the best of its territory. Most of this book is devoted to a study of the inhabitants already living in the forest among whom the second author has made several journeys. Two types of inhabitants are discussed, the indigenous folk, the Chunchos, and the immigrant stock which, coming from the mountains to the west, has settled in the woods or found temporary occupations. The former live in little river-side communities in which there are seldom more than three houses or about a dozen souls. They cultivate a little, hunt a little, and fish a little, and consequently have a varied diet containing many fresh items, and are in general well nourished. They are conversant with the herbs that supply many important drugs and know most of their curative properties. Their habits and occupations are sufficiently varied to resist that ennui which is the chief psychological problem of all dwellers in rain forest if they are not to go under, and they are in general healthy and robust. The colonists on the other hand live together in much larger groups and work as labourers on some plantation. They live on farinaceous foods with occasionally some second-rate dried meat, often somewhat decayed; and hardly ever have fresh meat, fish, or green vegetables. They soon show signs of this poor feeding and have little resistance to the many diseases ready to fall upon them. After work they have

no really diverting pastime. Hook worm is very prevalent, sores and fever, eye troubles, and venereal disease afflict them, and there are some who eat earth. The healthy Chunchos eat coca without much ill effect, but it soon produces a listlessness amongst the colonists who also make free use of the fiery spirit *chacta*. Condemnation is meted out by the authors to the Adventist Mission of Susique in which the mode of life and diet dispensed are not suitable or adequate to nourish the children for whom they care.

In spite of this damning analysis it is concluded that colonists may be introduced and kept healthy under good leadership and strict hygiene. Entertainment must be provided as an essential to keep such isolated communities happy. The difficulty seems to the reviewer to be one of finance, because profit on agricultural produce at such a distance from the market is eaten up in transport costs, and it is difficult to see whence endowment may come. Where economic gain is assured a healthy camp can easily be maintained under similar rain-forest conditions, as has been proved for instance in the Magdalena Valley in Colombia, but it involves relatively high out-goings both capital and current. The book is lavishly illustrated and makes stimulating reading for all interested in the interaction of diet and environment. J. V. H.

AUSTRALASIA AND PACIFIC

THE PHYSIOGRAPHY OF VICTORIA: an introduction to geomorphology. By E. Sherbon Hills. *Melbourne: Whitcombe and Tombs, Ltd.*, 1940. $8\frac{1}{2} \times 5\frac{1}{2}$ *inches;* xx+292 *pages; sketch-maps, diagrams, and photographs.* 8*s* 6*d*

This is an interesting book and one that should be welcomed for two reasons in particular. First it is clear evidence of the interest now taken in Australia in physiography and physical geography; the author has had the geographer very much in mind. Secondly, while it is of undoubted value to students in Australia, readers in this and other countries will find in it admirable illustrations drawn from an area with which few are familiar.

Most of the book is really an introduction to the study of land forms, and only the last two chapters deal with Victoria in any detail. On the other hand nearly all the illustrations, whether pictorial or descriptive, are taken from examples in Victoria. It is hardly a quibble to suggest that the title might have been 'An introduction to geomorphology as illustrated in Victoria.' This is in no sense an adverse comment: it merely stresses for the non-Australian reader the main trend of the volume.

Throughout the author has paid great attention to photographs, diagrams, and maps. In this and other ways he has followed to some extent the lead given by C. A. Cotton in his work on New Zealand. Most of the photographs are well reproduced: it is a pity that some of them are blurred. The examples are well chosen and also interesting. Teachers of the subject in this country should be glad to have new instances with which to illustrate their talks. The treatment is elementary, but clear, and if the general principles of the subject are not strange, the author has succeeded well in providing his readers at home with a book that will impress upon them the interest and context of their subject. If a student can see things for himself it is the best help, and as so many text-books on this subject are limited to Europe or North America, it is an obvious advantage for the Victorian reader to know that he can find really good features illustrating physiographic processes in his own state.

A few comments in detail may be made. Eskers are not necessarily regarded as being formed in tunnels under the ice. No discussion is given to the differences between eskers and kames, but the notion, first put forward by de Geer,

that true eskers are in the nature of deltas in glacial lakes would have been helpful. Firn is also made distinct from *névé*: are they not two words of different languages referring to the same thing? In fact, the chapter on the work of glaciers appears to be rather below the standard of the others—perhaps because Victoria is not the most suitable place to illustrate glacial action. The nature of cliffs will depend much on the nature of the rocks, bedding, dip, joints, etc.: it is hardly sufficient to say that the slope of the cliff face depends upon the rapidity of wave erosion and the ease of atmospheric weathering. Again, in referring to fiords, the author says that the frequent rectangular pattern shown by fiord systems "is determined by the glaciers having eroded their valleys along belts of structural weakness such as faults or shatter belts, which cross each other approximately at right angles." Unintentionally perhaps this seems to be riding very close to the tectonic origin of fiords—a view, to say the least of it, not acceptable to all physiographers.

These however are small blemishes. It is to be hoped that the volume will be widely accepted in Australia and elsewhere, and if a second edition becomes necessary the author, although he says in his preface that for detailed discussions reference should be made to original papers, might possibly consider adding some discussions of controversial matters. Not only would the present volume become a more valuable source-book on the physiography of Victoria, but further it is not always easy for the reader to turn to original papers in scientific journals, especially when he has not ready access to a library. Dr. Hills has given us a very useful book. J. A. S.

THE DISCOVERY OF NEW ZEALAND. By J. C. BEAGLEHOLE. (New Zealand Centennial Surveys, 2.) *Wellington: Dept. of Internal Affairs*, 1939. 8×5½ *inches;* xviii+160 *pages; illustrations and map.* 5*s*

This book is one of the New Zealand Centennial Surveys, which are being published by the Government of the Dominion "to present a comprehensive picture of the nation's development." Dr. Beaglehole is well known for his book 'The exploration of the Pacific,' published in 1934, which deals with the discovery of New Zealand in a larger frame than is attempted in the book here under review. This shorter volume is more in the nature of an essay and treats only of the discovery of the coast-line, as the exploration of the interior is described in another book of the same series. The work of the early Maori voyagers, of Tasman and the Dutch, of James Cook, and of the French explorers, de Surville, du Fresne, and d'Urville are all considered, and the account of this last group of explorers is particularly valuable. The appendixes include an amusing record of Maori reminiscences of Cook (known here as the goblin chief), that were taken down in 1852, and also an extremely useful bibliography of printed and unprinted sources. Nothing but praise can be given to the illustrations, the beautiful typography, as well as to the style of the book, written with such lucidity and bearing its scholarship so lightly. Great credit must be given to the Department of Internal Affairs of the New Zealand Government for publishing so attractive a volume. E. W. G.

AUSTRALIA: a study of warm environments and their effect on British settlement. By GRIFFITH TAYLOR. *London: Methuen and Co.*, 1940. 8½×5½ *inches;* xvi+456 *pages; illustrations, sketch-maps, etc.* 21*s*

This volume is designed to provide an advanced text-book of Australian geography on modern lines, the lack of which has been apparent for some time. Professor Griffith Taylor's qualifications for undertaking such a work include in particular a mass of observations drawn from much travel and field study, both

in Australia and elsewhere, experience in University schools, and above all an enthusiasm for the extension of sound geographical knowledge. This book has therefore a strong individual impress, which not only enlivens the text periodically, but has also influenced its construction. It is in fact, as well as a systematic treatment of the subject, a demonstration of his methods of geographical technique, and a record of his contribution to the understanding of Australian problems.

At the outset he discusses briefly the possible methods of approach, and favours that of regional studies, in which emphasis is placed upon the geological and topographical elements of the environment. He cites de Martonne's volumes on 'Europe Centrale' as a typical example of this method, but it may be observed that de Martonne brings the human aspects into closer relation with these regional studies than Professor Taylor has done, and that actually regional studies occupy a relatively small number of his pages. The author's general position is illustrated by his dictum: "Man himself can do nothing with a land until nature has spread her green mantle thereon," a statement which surely requires some qualification.

It is of interest to note that despite his use of natural regions his attitude towards them is purely practical. Allowing that "as is perhaps to be expected, there is no unanimity as to how uniform or how small such regions should be," he finds that "the practical answer is to decide on the number of subdivisions required (for example about twenty) and then to try to carve Australia into twenty areas in each of which the desired uniformity is approached as close as may be." These natural regions therefore are adopted as a practical device for dealing most conveniently with the varied facts of topography, climate, and vegetation, while of course demonstrating their mutual relationships. No attempt is made, perhaps wisely, to define their limits at all precisely. Thus the first region, Canberra, is given as including "that portion of the Eastern Warp which lies west and south of Sydney and Newcastle." After a brief general physical description, there is a more detailed treatment of the Sydney area, followed by a sketch of the history of settlement there, and then a return to the topography of the remainder of the region. Its relation to that to the north, the New England region, is not set down, though it may not be a bad thing to leave the reader to find this out for himself. Again, if the Victoria natural region be taken, it will be found to be treated topographically in three sections, one of which, the Eastern Highlands, is structurally associated with the south-east New South Wales. The difficulty of assigning areas to regions is shown also in his region No. 10, the Lake Eyre Basin. The structural history of most of this area would appear to relate it to the Flinders region: it lies however in the Geosyncline, but is separated from the major region of this division on climatic criteria. Incidentally it figures on p. 129 in the column headed "temperate, mostly winter rain," though from the graph to which on p. 190 the reader is referred, the maximum rainfall is shown as in January.

Perhaps too much attention has been given here to these details of regional division, but the author lays much stress upon them. This part of some eighty-five pages is preceded by 125 pages on world position and general physical elements, with emphasis on climate and vegetation: it is followed by the longest part entitled "The environment as related to man." This includes chapters on the progress of settlement, agriculture, the pastoral industry, minerals, etc., and the work concludes with a discussion of problems of tropical settlement and of population. It is no doubt partly because of the form of the statistical material that much of these chapters is on a state basis, and is not referred directly to the regional divisions. Throughout the text is supplemented with sketch-maps,

block diagrams, and graphs, and much attention is given to climatic comparisons with other parts of the world.

In his final discussion of the much-debated question of the future population of Australia, the author's approach is cautious, and he emphasizes the relative order of the values of the settlement zones rather than the absolute figures to which they may attain. Griffith Taylor, as he proclaims in the closing pages, is a determinist, but surely it weakens his argument to realize that many of the assumptions which have to be made in such a discussion of future population will conceivably depend on trends outside Australia. It is true, as he urges, that men do not now take fertilizers to the "barren grounds" of Canada, but less than one hundred years ago they would not have thought of taking them to the prairies, much less, for example, to the Peace River. Man, he argues, alters "the rate, but not the direction of progress": but surely where he destroys forest or sward, and initiates large-scale erosion, he is changing the direction of "nature's plan." G. R. C.

PHYSICAL AND BIOLOGICAL GEOGRAPHY

THE RHYTHM OF THE AGES. By A. W. GRABAU. *Peking: Henri Vetch,* 1940. 10×6½ *inches;* xviii+562 *pages; maps and diagrams.* 20*s*

Dr. Grabau is a distinguished palaeontologist who has spent the last twenty years in China. For him the rhythm of the ages is of course the geological rhythm of oceanic transgression and regression, or, as he prefers to call it, pulsation and interpulsation periods. Marshalling his vast stratigraphical knowledge, he rewrites the history of the globe from its infancy, but in doing so he takes such liberties with astronomy and dynamics as must make the reader very reluctant to accept his arguments. It is significant that the name of Dr. Harold Jeffreys does not appear in the bibliography, in which indeed sixty-eight entries refer to the author's own writings over a period of nearly half a century, while one hundred and six refer to other writers.

The main lines of his thesis are as follows. The sial originally formed a uniform shell covering the whole globe, and itself being covered by a world-wide ocean. The appearance of dry land was due to the attractive force exercised by a "stellar visitor" which occupied a position relative to the South Pole that the Pole Star occupies to-day in relation to the North Pole. This heavenly body drew the sial together into a Pangaea, while the oceans gathered upon the exposed surface of sima as a Panthalassa. The sial was crumpled in the process, both in a meridional and in an east–west direction, these crumplings giving birth to the pre-Cambrian mountain ranges. The difficulty is not faced that if the sial cover of the northern hemisphere is to be drawn across the equator it will have to be slit apart. Meanwhile the stellar visitor vanishes, making however a possible reappearance at the beginning of the Palaeozoic era in order to pull up the outer rim of Pangaea into "old lands" separating geosynclines from Panthalassa. It is during the Palaeozoic period that Dr. Grabau finds the evidence for the series of pulsations, of advances and retreats of Panthalassa, that are his main theme. To explain them he accepts Joly's hypothesis of the alternate melting and resolidification of the sima, with resulting diminution and increase of the "freeboard" of the sial mass, and with resulting stresses and tensions as the changing volume of the outermost shells of sima make them "misfits" over the core of the globe.

It is to be remarked that Dr. Grabau nowhere considers the contraction of the globe as a factor in mountain building, indeed he hardly considers even the

"Joly" effects, for he is committed to a further hypothesis which necessitates complicated movements of Pangaea, assumed in themselves to result in mountain building. This hypothesis, or rather theory, is that glaciation (except on high mountains) can only be immediately circumpolar, *i.e.* well within the frigid zones, and hence pole-wanderings become a necessity. These are brought about by assuming that Pangaea will gyrate "now clockwise now anti-clockwise" as a result of the rotation of the earth. The point about which gyration takes place is determined by an igneous (sima) intrusion which serves as a pivot, the sial being anchored at that particular point, but twisting freely about it. This pivot is shifted as the needs of the situation appear to require, and the query as to whether the forces generated by the earth's rotation are of the order required to overcome the resistance of the sima to these gigantic sial movements is not raised. The limitation of glaciation to circumpolar areas requires as a consequence extensive and rapid polar shifts during the Pleistocene, with the corollary also that the North American and European glaciations are not contemporary.

Rapid movements however seem to present no difficulty to the author, for it is not until the Cretaceous period, he considers, that the break up of Pangaea began with the opening of the Atlantic Rift. In early Holocene (Recent) times, he maps South America as still lying wholly south of the equator, firmly attached to Antarctica. Central America was then represented by an isthmian mountain belt covering 30 degrees of latitude. But eventually "South America was torn violently from the grip of Antarctica," and "divorced from its steadying companion . . . now became the prey of the centrifugal forces of the rotating globe, and 'Pol-flucht' escape from polar captivity resulted. This caused the crumpling of the Isthmus into the remarkable 'hair-pin' or 'tuning-fork loop' which it now presents." Nor has South America been the only recent traveller. Eastern Asia has swung northward since the Würm glaciation, in the case of Saghalien by 20 degrees of latitude, the tropic running then through North Central China and Japan. The pivotal movement which carried East Asia northwards brought southern Spain from latitude 60 degrees to its present position, southern Italy too, was only 30 degrees from the Pole, in the latitude, that is to say of present day Finland. But post-glacial time is measured in mere millennia, and a movement through 20 degrees of latitude measures over 2000 kilometres. Supposing it to be spread over one hundred thousand years, the journey would be one of 20 metres yearly. Unless we are to suppose that all sial movements have now abruptly stopped, changes of position of this order of magnitude could hardly escape the notice of surveyors, with nearly a century of precise observations behind them.

Many other objections present themselves, but it is the prerogative of the veteran to be provocative, and it is undoubtedly true that the speculations of Wegener, Joly, Holmes, Daly—to name but a few—have been of untold value as a stimulus to the study of earth history. Nevertheless to create *ad hoc* a stellar visitor, and as arbitrarily to return it to limbo, is to recall to the student of the history of science the efforts made by seventeenth-century writers to explain Noah's Flood in the light of the New Learning. E. G. R. T.

ECONOMIC AND HISTORICAL GEOGRAPHY

LIVINGSTONE THE LIBERATOR: a study of a dynamic personality. By JAMES I. MACNAIR. (Library of Classics.) *London and Glasgow: Collins*, 1940. $6\frac{1}{4} \times 4$ *inches;* 382 *pages; illustrations and sketch-maps.* 2*s* 6*d*

This little book contributes fittingly to the celebration of the centenary of Livingstone's first departure for Africa, 8 December 1840, and forms in small

compass an excellent summary and appreciation of his life-work and personality. It is valuable too for the new sidelights thrown on the subject from unpublished documents recently brought together, many now suitably housed in the Scottish National Memorial at Blantyre, Lanarkshire. Both as a Scotsman himself and as Chairman of the Memorial Trust, Mr. Macnair was eminently fitted to undertake this new addition to the "Library of Classics," and his full knowledge of the facts and deep sympathy with the aims and achievements of the great philanthropist are clear throughout. After an unusually full sketch of Livingstone's early years the book is divided into sections coinciding with the plan of the Blantyre Memorial, under the heads of Missionary, Explorer, Consul, and Martyr, with many picturesque touches bearing on Livingstone's personality. It could hardly be expected that new light should be thrown on his work as an explorer, but even here the use of his private diary adds some intimate details, as in the account of the critical situation at the Loangwa river during the eastward route in the first great journey. But it is the wider aspects of Livingstone's work for Africa that naturally receive the chief emphasis, as is already indicated by the title. The illustrations include reproductions of the statuary groups executed for the Memorial by Mr. Pilkington Jackson, and of two water-colour sketches, together with photographic portraits, etc. There are also outline maps showing the routes of the several journeys. E. H.

DAS BYZANTINISCHE REICH ALS GEOGRAPHISCHE ERSCHEInung. By Professor ALFRED PHILIPPSON. *Leiden: E. J. Brill*, 1939. 6½×10 *inches;* viii+214 *pages; maps*

Professor Philippson's introduction, on the geography of the Mediterranean in general, covers familiar ground, but his treatment of it is pleasant and concise. The isolated western provinces of the Empire, in Italy, North Africa, and Spain, are perhaps somewhat cursorily dealt with, but these were soon to fall away from the main body: when he comes to Asia Minor, the core of the Empire, the author is very much on his own ground, and the treatment is more extended, though physical geography is always the main theme, to which other aspects are subordinate. There is little that is new in the book, but as a summary or revision it has value. Professor Philippson has an attractive way of dealing passing blows at popular heresies (the belief that the Karst was deforested by the Venetians to obtain wood for their ships, or that Malmsey took its name from the Monemvasi in the Peloponnese); but it may be wondered whether he is not perpetuating one when he traces the Greek still spoken in southern Calabria back to the seventh century. In his conclusion he points out that the influence of the geographical factor must not be exaggerated. Herein lies a weakness in the study, for the author does not deal with the other factor, the human organization that kept in being an Empire born fully fledged and destined to suffer steady loss of territory. The Byzantine Empire is in fact less impressive as a geographical than as a spiritual phenomenon, for its lasting influence extended over many territories that never acknowledged its temporal rule.

There are selected references and short bibliographies to the chapters; the sketch-maps hardly suffice. J. P. H. M.

THE MONTHLY RECORD

COASTAL LANDSLIPS OF SOUTH-EAST DEVON

In a short paper in the *Proceedings* of the Geologists' Association, vol. 51, 1940, pt. 3, Miss M. A. Arber discusses the coastal landslips of south-east Devon. The most spectacular landslip on the English coast occurred at Dowlands, near Axmouth, at Christmas 1839, but this is one only of a series which have taken place between the mouth of the River Axe on the west and the county boundary on the east. Here the Cretaceous rocks, chalk, upper greensand, and gault, overstep the eroded surface of Triassic, Rhaetic, and Liassic clays, the plane of denudation and the overlying beds being inclined about 5 degrees towards the sea. Water percolating downwards accumulates on the surface of the clays, and is liable to wash away the sands, which may slide towards the sea, carrying the chalk with them. At Hooken Cliff, where the plane dips below sea-level, an area of about 10 acres subsided in March 1790; the sea encroached about 200 yards on the land, and the sea bottom was forced up as an offshore reef. The Axmouth landslips form a tumbled tract for 4 miles eastwards of Culverhole Point. The tract is about a quarter of a mile wide between the sea and the inland cliffs, which rise in parts to 500 feet. The more recent movements have taken place at Dowlands and Bindon cliffs. The second half of the year 1839 had been exceptionally wet, with twice the normal rainfall, and there had been long and continued gales. Fissures had been noticed early in December, subsidence began early on Christmas morning, and the main slip took place that night, when coastguards heard a deafening crash of falling rocks and saw the beach heaving and a dark ridge rising in the sea. By the evening of the 26th a position of equilibrium had been reached. The chasm thus formed, isolating a strip of cultivated land, was about half a mile long and from 200 to 400 feet wide, backed by an inland cliff of 210 feet. The displaced sea cliffs had been broken, lowered, and thrust 50 feet seawards. The dark ridge proved to be a reef of greensand, 300–500 feet seaward of the former high-water mark, with beds now dipping sharply inland. It is estimated that 8 million tons of rock had foundered. Two prominent geologists, Conybeare and Buckland, visited the site immediately afterwards, collected much interesting information, and explained the cause of the fall on the lines now accepted. The public refused to accept the reasoned explanations of the geologists: the fall was widely attributed to a volcano or earthquake, and alarm was widespread. No important falls have occurred during the last hundred years, though fissures are gradually opening in the edge of the Dowlands cliff, and further subsidence is probable.

NEW WORLD ORIGINS

Mr. J. G. D. Clark gives in *Antiquity* for June 1940 a critical summary of present knowledge of human origins in the New World, with a select list of references to the literature. He starts from Clark Wissler's generalization that "New World culture is [thus] a kind of pyramid whose base is as broad as the two Americas and whose apex rests over Middle America." The autochthonous development of the higher forms of Middle American culture has now been established as against the wide claims of the diffusionist school, and the ability of the early inhabitants to evolve their own civilization independently is supported by their successors' achievements in domesticating the llama, alpaca, guinea pig, and turkey, and also many plants, *e.g.* maize, potatoes, tobacco, and tomatoes. The primitive new world cultures, now to be studied mainly on the extreme confines of the land-mass, possess an underlying similarity pointing to a

common origin and a general somatic homogeneity of the race. The author first approaches these problems from the point of view of prehistoric archaeology. The new world may be regarded as two provinces of primitive culture separated by the advanced culture of the middle: it is possible therefore to check the elements of the northern and southern cultures against each other, thus to eliminate the effects of diffusion from more advanced regions. This method can also be controlled by results from the excavation of stratified sites. The main aspects of the early immigrant culture are taken to be an economy based on hunting and food gathering, knowledge of basketry, etc., ability to flake stone, and the use of clubs, harpoons, spears, and spear throwers; the features lacking being knowledge of agriculture, use of pottery, and the practice of metallurgy.

In 1928 flint points of a distinctive type in association with the remains of extinct bison were excavated at Folsom, New Mexico, and knowledge of the Folsom culture has since been further extended, to open a new era in American pre-history. These bison hunters appear to have ranged the High Plains from south Wyoming to western Texas: they were nomads using skins for tents, perhaps also for vessels, and hunting with spear-throwers. The little that is known of them conforms to the postulated immigrant culture. Besides the Folsom type, there are the similar Folsom-like and Yuma points, which have a much greater range. The age of the Folsom type is as yet undetermined, since there is no agreement on the period at which the mammals with which they are associated died out. Some indication as to the lower limit is provided by geology. No human remains or artifacts have been found beneath the deposits of a major glaciation, so that man probably reached America after the maximum of the last glaciation. Access to central North America would therefore be barred until the Wisconsin ice-sheet was well in retreat. Its melting would open a way from central Alaska to the Great Plains, eastward to the Mackenzie and then south along the foot of the Rockies. An approximate upper limit can be derived from an examination of the higher cultures of middle America; from these it appears that the Folsom food-gatherers cannot have arrived later than the second millenium B.C. These limits give however a wide margin, ranging from 12,000 to 1000 B.C., and until more is known of the history of climate, animals, and plants since the last ice age in America, no precise dating will be possible. The evidence of physical anthropology is that man came to the New World from northern Asia in geologically recent times, and this supports the above conclusions. The route of early immigrants into America would lie outside the limits of cereal cultivation, and would be open therefore to food-gatherers only, that is, to people belonging to the same world as Palaeolithic and Mesolithic man in Europe.

Little is known of prehistoric cultures in northern Eurasia, but it is possible to picture from sites in the Irkutsk and Krasnoyarsk regions the existence of a Mesolithic food-gathering people in a stage of development corresponding to the Folsom, and it may have been these who, under pressure from food-producing people, spread to the New World. This hypothesis of its peopling by migrants of Mesolithic status explains many parallels often drawn between the cultures of the Americas and northern Asia.

EXPEDITION TO THE PATAGONIAN CORDILLERA

Dr. Arnold Heim describes in *Die Alpen* for August 1940 a recent expedition to the eastern Patagonian Cordillera. The region had long attracted his attention; there in 46° 50′ S., about as far south of the equator as Switzerland is to the north, is the highest summit in Patagonia, the Cerro San Valentin, 4058 metres; on the east the Lago Buenos Aires, at a level of 227 metres, penetrates

for 130 kilometres into the glaciated Cordillera, thus offering an unusual opportunity for geological and glaciological studies: to the west extends as far as the Pacific a great icefield comparable to that of Greenland. The Swedish geologist Caldenius had studied glacial deposits at the eastern end of Lago Buenos Aires, but little was known of the region to the west. Dr. Heim's plans included an attempt to cross the Cordillera in this latitude.

Owing to difficulties in transmitting supplies and equipment from Switzerland, Heim was detained for a month in Valparaiso, and it was not until 5 December 1939 that his party left Osorno, a delay that was to prove serious. He was accompanied by H. Hess, a guide from Engelberg, W. Schmitt, an experienced climber, and three Chilean porters; he was to be joined later by H. Moser, and Dr. J. Neumeyer as medical officer. The latter however was obliged to withdraw. The equipment included ski, light sledges, and a folding boat. Travelling by steamer from Puerto Montt the party reached Puerto Aysen, crossed the Cordillera to the Argentine pampa, and then struck southwards for the eastern end of Lago Buenos Aires. After some difficulty in crossing rivers, they arrived at Chile Chico, on the southern shore of the lake. Here the party divided into two sections: Hess and Schmitt proceeded to the western end to establish a camp as close to the icefield as possible, while Heim spent ten days in geological field work. From the mountains on the north shore he had his first sight of San Valentin, an ice-covered mountain block with steep ice-walls on the south, north, and east. On the small lake steamer he reached the western end, and went up the Valle Leon, being hospitably received by the sheep farmer established there. Westerly gales were now blowing; the air was filled with dust, and he was able to watch the formation of loess deposits, the dust settling on the lee sides of the valley hillocks. Smoke from the burning forest was also continuous, for the settlers fire the beech forests to obtain more clearings for their sheep, and to deprive the pumas, which prey upon their flocks, of shelter. Dr. Heim remarks that this uncontrolled destruction will soon remove the humus cover, and thus the sheep pastures. Twenty-five kilometres up the Val Leon he reached a lake, the Lago Leon, surrounded by a 100–140 metre moraine wall, where he camped. At the western end three glaciers descending from the Cordillera unite to enter the lake. The next day was fine and clear, so that he was able to examine and photograph the mountains. The weather then broke, and, although midsummer, there was no fine day for three weeks. For some days Heim was practically confined to his tent. On December 28, Moser arrived to join the party, but was almost immediately attacked by abdominal pains, and was obliged to leave. On January 9, Hess came down from the glacier for the second time, and it was decided to move to the higher camp. The lake was very rough, but though the boat was eventually upset they reached the glacier wall, and climbed up to the camp on the eastern side of the southern Leon glacier at 1000 metres. Rain and snowstorms continued, and it was not until the fifth day that the weather cleared sufficiently to allow a view of the massif and its summits. Twenty-three kilometres to the N.N.W. they recognized the Cerro San Valentin. They were able to climb to 3000 metres on a nearby pyramid mountain, probably the Cerro Hyades of the maps. As there were no signs of the weather improving, and Dr. Heim's time was running short, he decided to return to Osorno. There he delayed his departure until he had received news of the others. Despite very bad weather, Hess and Schmitt succeeded in climbing to the inland ice at about 1800 metres on the north side of the Leon glacier. This was the first time it had been reached from the east. A few weeks later a party under Dr. F. Reichert succeeded in making the crossing from west to east.

It may be recalled that Lago Leon and three neighbouring lakes were first examined by a Chilean military and scientific expedition early in 1939 (see *Journal*, January 1940, p. 77).

SIR HUMPHREY GILBERT

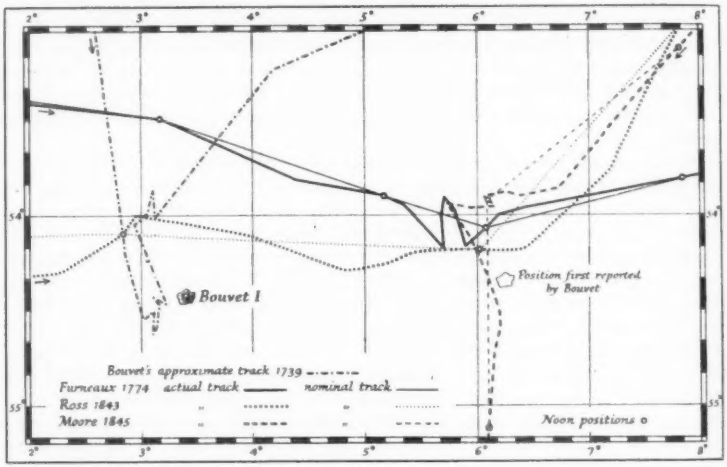
We have received from Mr. J. P. Ruthven a letter protesting against our review in the *Journal* for December last of Dr. Quinn's volumes of the Hakluyt Society, 'The voyages and colonising enterprises of Sir Humphrey Gilbert.' The writer infers that the reviewer has relied on the editorial introduction rather than on the ensuing documents, and as a veteran student of Gilbert's career considers it very misleading to use the term "disastrous failure" and to suggest that "his failure may be explained in part by faults of character." He considers that the plan for colonizing Newfoundland was frustrated not through any fault of Gilbert, but by his death on the homeward voyage, and that without him as leader and ruler of the suggested colony "English people were not disposed to leave home and hazard themselves in a new world." He considers that Gilbert was sufficiently financed for his last venture, for he had the backing of powerful statesmen and a promise of aid from the Queen herself. His own last letter to Sir George Peckham says that he found the outlook answerable to his best hopes, and Hakluyt in his first edition of 1589 said that Gilbert was "free of financial anxiety."

To this our reviewer would reply that the first paragraph of the review is admittedly a paraphrase of the views expressed by Dr. Quinn in his introduction, and this should have been made clear. As the documents printed by Dr. Quinn in his two volumes support his view of Sir Humphrey Gilbert and his colonizing enterprises, it is difficult to see how the dispassionate tenor of the introduction can be regarded as "disparaging" Gilbert's work. It seems indisputable that the purpose of his second voyage was "to discover and to plant Christian inhabitants in place convenient"; as this was not accomplished, it is permissible to refer to the voyage as a failure. When Mr. Ruthven writes that without Gilbert's leadership "English people were not disposed to leave home and hazard themselves in a new world," he is surely overlooking the establishment of the first English colony in Virginia two years after Gilbert's death. The statement that he had a promise of aid from the Queen appears to rest upon his remark to his crew on the return voyage that the Queen would lend him ten thousand pounds for another attempt, but the context suggests that this was made to encourage his men. This appears also to be the basis of the contention that he was "then free of financial anxiety." Writing to Sir Francis Walsingham shortly before his voyage, he had referred to the precious metals "to bee gotten without any charge to her majestie" and to his having sold land to equip the expedition. Whether the support he had obtained was sufficient for the successful accomplishment of his ambitious project seems doubtful. The difficulties in establishing a colony were not completely realized at the time: it is to Gilbert's credit that he foresaw the necessity of careful planning in advance, and it is no disparagement to point out that much of his time was spent in endeavouring to obtain adequate backing. Though Gilbert did not live to see the first English colony set up in North America, his life work, taking a broad view, was not ultimately without result. It was this aspect that the review attempted to emphasize.

THE TRACK CHARTS OF EXPLORERS

During recent discussion of several Antarctic problems we have received a letter from Lieutenant-Commander Rupert Gould, R.N. retd., from which, with his permission, we make the following extracts:

There is all the difference in the world between plotting the track of a sailing-ship and a steamship. That of a steamship is comparatively easy to plot from her log; that of a sailing-ship, unless very full information is available, often gives a very misleading impression. A very rough tracing shows three sailing-ship tracks at different dates in the vicinity of Bouvet Island; those of Furneaux (*Adventure*) 1774, Ross (*Erebus*—the *Terror's* track is very similar) 1843, and Moore (*Pagoda*) 1845. All three were in search of the island, and failed to find it; and, as the tracing shows, the track obtained by simply joining their noon positions is far from giving a correct idea of where they went. The actual tracks were obtained by first plotting the various courses and distances run, between observed noon positions, hour by hour (and oftener, if necessary), making due allowance for variation, etc., and obtaining thus a D.R. noon position for comparison with that observed. The difference between the two was then treated as the combined effect of leeway and current, divided proportionally, according to



the elapsed times, between alterations of course, and the resulting increments applied to correct the D.R. position at the end of each run on any particular course. In this way a corrected course was obtained which began and terminated at consecutive observed noon positions; and this I accepted as being the nearest which I could get to the actual track traversed by the ship—and as being, in all probability, not far from the truth. No one, I think, without using this method, could have anticipated the zigzags in Furneaux' track in 5°–6° E., or the big northward bight in Ross' track between 2° E. and 5° E.—an excursion of which there is no hint in his book (his account of his track is very misleading, and apparently based largely on his noon positions only) and which undoubtedly caused him to miss Bouvet Island, although he must have passed within masthead view of it. It is fair to add, though, that he was expecting to sight it in about 54° 20′ S., 6° 15′ E., where it was then charted.

Bouvet's expedition was the first ever fitted out for the specific purpose of Antarctic exploration, and his discovery of Bouvet Island in 1739 will always make a notable date in Antarctic history. I do not think that his track would be *very* difficult to plot, although it would necessarily be approximate, and largely

a matter of joining noon positions. Luckily, his sighting of Bouvet Island, whose position is now accurately known, gives an excellent means of correcting his rather shaky D.R. longitudes. I have inserted a small portion of his track on the tracing, to show what can be made of it. The best authority that I know is Dalrymple's 'Collection of voyages, chiefly in the South Atlantic Ocean' (B.M. 984 E 24), and his 'Chart of the South Atlantic Ocean, with Memoir' (B.M. Maps, 984 (11)).

OBITUARY

THE RT. HON. THE VISCOUNT WAKEFIELD OF HYTHE, G.C.V.O., C.B.E.

Three years after he came to London at the age of thirty-two, and five years before he founded the firm of C. C. Wakefield and Co., Ltd., which brought him in course of time his great wealth, Lord Wakefield had become a Fellow of our Society, having already travelled several times round the world. When he died, on January 15 at the age of eighty-one, he had benefited by his far-seeing and imaginative generosity a wider extent of British institutions and interests than any Englishman can have done before. His money was given freely in the usual channels of beneficence, to great hospitals, orphanages, and benevolent societies; and equally freely to learning and research: to the British Academy, the Imperial Institute, and the National Museums, sometimes to their endowment or development, at other times even more remarkably by securing for them the Thomas à Beckett Cup, the Armada Jewel, the Great Chronicle of London, and Nelson's log-book in the *Victory*. He made possible the long pioneer flights of Sir Alan Cobham and Miss Amy Johnson, and Sir Henry Segrave's speed trials at Daytona and Miami. He was Lord Mayor of London in the critical year 1915–16, served as Master of four City Companies, and endowed the Tower Hill Improvement Trust. He founded scholarships for R.A.F. cadets at Cranwell, and a lectureship in history to commemorate the tercentenary of Sir Walter Raleigh. It is natural to feel in present circumstances that of all this wide generosity the most inspired was his early support of long-distance flying and the development of speed in the petrol engine.

His many interests left him little time to take an active part in our affairs, but his discriminating help to exploration came from a real comprehension of the explorers' ideas and work. When Mr. Rymill was arranging his expedition to the Antarctic funds were short. The member of Council who was helping Mr. Rymill applied to Lord Wakefield and received a cheque for £500. Three years later the expedition, their work successfully completed, came home. When the accounts were made up there was a deficit, not unusual in such cases. The same member of Council sent a copy of the accounts, without comment, to Lord Wakefield. Soon came a cheque, with a sympathetic reference, for £1000. The member referred to took Mr. Rymill to thank Lord Wakefield and left them together. Soon Lord Wakefield said: "This appeals to me; I see young men ready to risk in unselfish endeavour not only their future but their lives. I see the accounts are not quite square. What would you say if I gave another £1000?" and he handed a cheque for that amount across the table.

MEETINGS: SESSION 1940–41

Eighth Meeting, 6 January 1941. The President in the Chair

Elections: Dr. Rowland V. Bingham; Ivor William Major Dollar, B.A.; Urban J. Linehan; Dennis Clifford Mitchell; James A. Quinn, PH.D.; E. T. W. Robinson; Rev. Leonard Sale-Harrison, D.D.; Mrs. A. Margery Sale-Harrison; Miss Cicely Mary Willis

Paper: Crete as a place to live in. By Miss Sylvia Benton

Ninth Meeting, 13 January 1941. Mr. J. M. Wordie, Honorary Secretary, in the Chair

Paper: Water-levels in the Thetford meres. By Professor O. T. Jones and Mr. W. V. Lewis

Tenth Meeting, 20 January 1941. Lord Moyne, Vice-President, in the Chair

Elections: Leonard John Holman Berry, B.A.; The Rev. William Henry Blight; Lieut.-General Sir Charles A. C. Godwin, K.C.B., C.M.G., D.S.O.; Sir John Russell, D.SC., F.R.S.

Paper: Routes anciennes en Afghanistan. Par le Commandant J. Hackin, Forces Françaises Libres

Eleventh Meeting, 27 January 1941. Geographical films of India and South Africa with sound commentaries, lent by the Imperial Institute